Juvenile Salmonid Monitoring in Battle Creek, California, October 2002 through September 2003

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Juvenile Salmonid Monitoring in Battle Creek, California, October 2002 through September 2003

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Abstract- In October 2002, the U.S. Fish and Wildlife Service continued an ongoing juvenile salmonid monitoring project on Battle Creek, California, using rotary screw traps. Battle Creek, a tributary of the Sacramento River, is important to the conservation and recovery of federally listed anadromous salmonids in the Sacramento River watershed because of its unique hydrology, geology, and habitat suitability for several anadromous species. Information about juvenile salmonid abundance and migration in Battle Creek is necessary to guide efforts at maintaining and eventually restoring populations of threatened and endangered anadromous salmonids. From October 2002 through September 2003 four runs of Chinook salmon *Oncorhynchus tshawytscha*, rainbow trout/steelhead *Oncorhynchus mykiss*, and 14 species of non-salmonids were captured in either the Lower (LBC) or Upper Battle Creek (UBC) rotary screw traps. To determine rotary screw-trap efficiency, we conducted 18 and 20 mark-recapture trials at the LBC and UBC traps, respectively during January 22 through May 20, 2003. Individual and pooled trap efficiencies ranged from 0.073 to 0.242 at LBC and 0.031 to 0.082 at UBC. Chinook salmon run designations were made using length-at-date criteria developed for the Sacramento River, which resulted in underestimates of spring and overestimates of fall Chinook salmon production at both traps. The brood year 2002 spring and fall Chinook salmon passage estimates at the LBC trap were 2,315 and 581,677 respectively. The brood year 2003 late-fall Chinook salmon passage estimate at the LBC trap was 31,538. The annual passage of winter Chinook salmon was not estimated for the lower trap because of low catch rates (N=104) and because they were likely using Battle Creek for non-natal rearing. The passage estimate for age 1+ rainbow trout/steelhead at the LBC trap was 577 and 2,313 for brood year 2003 young-of-the-year. Brood year 2002 spring Chinook salmon passage at the UBC trap was 955. The brood year 2002 fall Chinook salmon passage estimate at the upper trap was 17,783. The brood year 2003 late-fall Chinook salmon passage estimate at the UBC trap was 6,702. Passage estimates were not made for winter Chinook salmon at the upper trap as catch rates (N=1) were too low. The passage estimate for age 1+ rainbow trout/steelhead at the upper trap was 592 and 7,145 for brood year 2003 young-of-the-year. Poor habitat conditions including low flows and high water temperatures during the summer and fall, and high scouring flows in the winter combined with high levels of pre-spawn mortality of fall Chinook salmon below the barrier weir and spring-run above the barrier weir may explain the decreases observed in juvenile salmonid passage at the LBC and UBC traps. High fall Chinook salmon pre-spawn mortality below the barrier weir was likely due record high adult escapement (397,149) and limited spawning area; while high spring Chinook salmon pre-spawn mortality above the barrier weir was due to low flows and warm water temperatures during the holding and spawning periods. In addition, decreases in adult escapement may explain the decreases in late-fall Chinook salmon and rainbow trout/steelhead juvenile passage.

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Introduction

In recent decades, California has experienced declines in several of its wild salmon and steelhead populations. These declines have been linked to a variety of factors, but the development of federal, state, municipal, and private water projects is likely a primary contributing factor (Jones and Stokes 2005). As a result of the declines, two populations of Chinook salmon (*Oncorhynchus tshawytscha*) and one population of steelhead (*O. mykiss*) in the Sacramento River watershed have been listed as threatened or endangered under the Endangered Species Act (ESA) or the California Endangered Species Act (CESA).

Battle Creek, a tributary of the Sacramento River, is important to the conservation and recovery of federally listed anadromous salmonids in the Sacramento River watershed because of its unique hydrology, geology, and habitat suitability for several anadromous species and historical land uses (Jones and Stokes 2005). Restoration actions and projects that are planned or have begun in Battle Creek focus on providing habitat for the endangered Sacramento River winter Chinook salmon, the threatened Central Valley spring Chinook salmon, and the threatened Central Valley steelhead. Currently the geographic range of the winter Chinook salmon Evolutionary Significant Unit is small and limited to the mainstem of the Sacramento River between Keswick Dam and the town of Red Bluff, California, where it may be susceptible to catastrophic loss. Establishing a second population in Battle Creek could reduce the likelihood of extinction. Battle Creek also has the potential to support significant, self-sustaining populations of spring Chinook salmon and steelhead.

Since the early 1900's, a hydroelectric project comprised of several dams, canals, and powerhouses has operated in the Battle Creek watershed. The hydroelectric project, which is currently owned by Pacific Gas and Electric Company (PG&E), has had severe impacts upon anadromous salmonids and their habitat (Ward and Kier 1999), including a reduction of instream flows, barriers to migration, loss of habitat, flow related temperature impacts, etc.

In 1992, the Central Valley Project Improvement Act (CVPIA), federally legislated efforts to double populations of Central Valley anadromous salmonids. The CVPIA Anadromous Fisheries Restoration Program outlined actions to restore Battle Creek, which included increasing flows past PG&E's hydroelectric power diversions to provide adequate holding, spawning, and rearing habitat for anadromous salmonids (USFWS 1997). Prior to 2001, PG&E was required under its Federal Energy Regulatory Commission (FERC) license to provide minimum instream flows of 0.08 m^3/s (3 cfs) downstream of diversions on North Fork Battle Creek and 0.14 m^3/s (5 cfs) downstream of diversions on South Fork Battle Creek. However, from 1995 to 2001, the CVPIA Water Acquisition Program contracted with PG&E to increase minimum stream flow in the lower reaches of the north and south forks of Battle Creek. This initial flow augmentation provided flows between 0.71 and 0.99 m^3/s (25 and 35 cfs) below Eagle Canyon Dam on the north fork and below Coleman Diversion Dam on the south fork.

In 1999, PG&E, California Department of Fish and Game (CDFG), U.S. Fish and Wildlife Service (USFWS), U.S. Bureau of Reclamation (USBR), and National Marine Fisheries Service (NMFS) signed a Memorandum of Understanding (MOU) to formalize the agreement regarding the Battle Creek Chinook Salmon and Steelhead Restoration Project (Restoration Project). The planning, designing, and permitting phases of the Restoration Project have taken longer than originally anticipated; therefore, funds for increased minimum flows in North and South Fork Battle Creek from the CVPIA Water Acquisition Program ran out in 2001. However, the federal and State of California interagency program known as the CALFED Bay-Delta Program (CALFED) funded the Battle Creek Interim Flow Project beginning in 2001 and will continue to until the Restoration Project begins. The intent of the Interim Flow Project (IFP) is to provide immediate habitat improvement in the lower reaches of Battle Creek to sustain current natural populations while implementation of the more comprehensive Restoration Project moves forward. Under the IFP, PG&E would maintain minimum instream flows at 0.85 m^3/s (30 cfs) by reducing their hydroelectric power diversions from May to October. In 2001, funding for the IFP was provided for the north fork, but not the south fork. In 2002, some of the north fork IFP flows were reallocated to the south fork under an agreement which allows for changing flows on either of the forks based on environmental conditions (i.e., water temperatures, numbers and locations of live Chinook salmon and redds). Beginning in late 2002, the IFP began providing the full minimum flow of 0.85 m^3/s (30 cfs) on both forks. In 2001, increased flows were provided only on the north fork in part based on observations of higher Chinook salmon spawning on the north fork than on the south fork. Redd counts from 1995 to 1998 indicated that 39% of spawning occurred in the north fork versus 23% in the south fork (J. M. Newton, USFWS, RBFWO, unpublished data).

The U.S. Fish and Wildlife Services' Red Bluff Fish and Wildlife Office (RBFWO) began using rotary screw traps to monitor juvenile salmonids on Battle Creek, Shasta and Tehama Counties, California, in September 1998 (Whitton et al. 2006). The purpose of this report is to summarize data collected during the period October 1, 2002 through September 30, 2003. This ongoing monitoring project has three primary objectives: (1) determine an annual juvenile passage index (JPI) for Chinook salmon (salmon) and rainbow trout/steelhead (trout), for inter-year comparisons; (2) obtain juvenile salmonid life history information including size, condition, emergence, emigration timing, and potential factors limiting survival at various life stages, and (3) collect tissue samples for genetic analyses.

Study Area

Battle Creek and its tributaries drain the western volcanic slopes of Mount Lassen in the southern Cascade Range. The creek has two primary tributaries, North Fork Battle Creek which originates near Mt. Huckleberry and South Fork Battle Creek which originates in Battle Creek Meadows south of the town of Mineral, California. North Fork Battle Creek is approximately 47.5 km (29.5 miles) long from the headwaters to the confluence and has a natural barrier waterfall located 21.7 km (rm 13.5) from the confluence (Jones and Stokes 2004). South Fork Battle Creek is approximately 45 km (28 miles) long and has a natural barrier waterfall (Angel Falls) located 30.4 km (rm 18.9) from the confluence (Jones and Stokes 2004). The mainstem portion of Battle Creek flows approximately 27.3 km (17 miles) west from the confluence of the two forks to the Sacramento River east of Cottonwood, California. The entire watershed encompasses an area of approximately 93,200 ha (360 $miles^2$; Jones and Stokes 2004). The current 39 km (24.4 miles) of anadromous fishery in Battle Creek encompasses that portion of the creek from the Eagle Canyon Dam on North Fork Battle Creek and Coleman Dam on South Fork Battle Creek to its confluence with the Sacramento River (Figure 1). Historically, the anadromous fishery exceeded 85 km (53 miles).

Battle Creek has the highest base flows of any of the Sacramento River tributaries between Keswick Dam and the Feather River, and flows are influenced by both precipitation and spring flow from basalt formations (Jones and Stokes 2005). The average flow in Battle Creek is approximately 14.1 m^3/s (500 cfs; Jones and Stokes 2004). South Fork Battle Creek is more influenced by precipitation and likely experiences higher peak flows, whereas North Fork Battle Creek receives more of its water from snow melt and spring-fed tributaries. Maximum discharge usually occurs from November to April as a result of heavy precipitation. Average annual precipitation in the watershed ranges from about 64 cm (25 inches) at the Coleman Powerhouse to more than 127 cm (50 inches) at the headwaters, with most precipitation occurring between November and April (Ward and Kier 1999). Ambient air temperatures range from about 0ºC (32ºF) in the winter to summer highs in excess of 46ºC (115ºF).

Land ownership in the Battle Creek watershed is a combination of state, federal, and private including the CDFG, Bureau of Land Management (BLM), and USFWS. Most of the land within the restoration area is private and zoned for agriculture, including grazing. Currently, much of the lower Battle Creek watershed is undeveloped, with scattered private residences, ranching enterprises, and local entities.

The RBFWO installed and operated two rotary screw traps on Battle Creek, the first site was located 4.5 km (rm 2.8) upstream of the confluence with the Sacramento River, and the second site was located 9.5 km (rm 5.9) upstream of the confluence (Figure 1). The lower trap site was designated Lower Battle Creek (LBC) and the upper trap site was designated Upper Battle Creek (UBC). The stream substrate at these locations is primarily composed of gravel and cobble, and the riparian zone vegetation is dominated by California sycamore (*Plantanus racemosa*), alder (Alnus spp.), Valley Oak (*Quercus lobata*), Himalayan blackberry (*Rubus discolor)*, California wild grape (*Vitis Californica*) and other native and non-native species.

Methods

Trap Operation

In October 2002, the Red Bluff Fish and Wildlife Office continued the operation of two rotary screw traps on Battle Creek. During the current reporting period (October 1, 2002 through September 30, 2003), the Lower Battle Creek trap (LBC) was operated from October 1, 2002 through July 29, 2003 while the Upper Battle Creek trap (UBC) was operated from October 10, 2002 through August 18, 2003. September 30, 2003 was designated the end of the current reporting period as it allowed us to estimate total passage for brood year 2002 (BY02) fall and spring Chinook salmon and total catch for BY02 winter Chinook salmon at the LBC trap. Although the designated reporting period does not include the total passage of brood year 2003 (BY03) late-fall Chinook salmon, complete passage estimates are reported as the data were available and it will prevent duplication in the 2003-2004 report.

The rotary screw traps, manufactured by E.G. Solutions® in Corvallis, Oregon, consist of a 1.5-m diameter cone covered with 3-mm diameter perforated stainless steel screen. The cone, which acts as a sieve separating fish and debris from the water flowing through the trap, rotates in an auger-type action passing water, fish, and debris to the rear of the trap and directly into an aluminum live box. The live box retains fish and debris, and passes water through screens located in the back, sides, and bottom. The cone and live box are supported between two pontoons. Two 30 to 46-cm diameter trees on opposite banks of the creek were used as anchor points for securing each trap in the creek, and a system of cables, ropes and pulleys was used to position the traps in the thalweg.

We attempted to operate the traps 24 h per day; 7 d each week, but at times high flows, hatchery releases, and staff shortages limited our ability to operate the traps continuously (Appendices 1 and 2). In addition, at times when few or no salmonids were captured, we did not operate the traps or operated them on a reduced schedule (usually 4 d per week). Traps were not operated when stream flows exceeded certain levels in order to prevent fish mortality, damage to equipment, and to ensure crew safety. The traps were checked once per day unless high flows, heavy debris loads, or high fish densities required multiple trap checks to avoid mortality of captured fish or damage to equipment. In addition, to improve the accuracy of our juvenile passage indexes (JPI's), we attempted to fish high flows when most juvenile salmonids are thought to outmigrate and increase the number of mark-recapture trials, which were used to estimate trap efficiency. When flows allowed, the crews were able to access the traps by wading from the stream bank; however, during high flows access to the traps required that the crews use the cable and pulley system to pull the traps into shallow water. After or during sampling and maintenance, the traps were repositioned in the thalweg.

In October 2000 the LBC trap was modified by placing an aluminum plate over one of the two existing cone discharge ports and removing an exterior cone hatch cover (half-cone modification). As a result, half of the collected fish and debris were not discharged into the live box, but rather were discharged from the cone back into the creek. This effectively reduced our catch of both fish and debris by half, and also reduced crowding of fish in the live box by half. During the 2002 to 2003 reporting period, the LBC trap was operated with the half-cone modification from December 3 to 5, 2002 to reduce the capture of late-fall Chinook salmon released by the hatchery. In previous years, additional modifications were made to the traps and daily operations to reduce the potential for impacts to captured fish and to improve our efficiency. Modifications to traps included increasing the size of the live boxes and floatation pontoons, and adding baffles to the live boxes.

Each time a trap was sampled, crews would sample fish present in the live box, remove debris from the cone and live box, collect environmental and trap data, and complete any necessary trap repairs. Data collected at each trap included, dates and times of trap operation, water depth at the trap site, cone fishing depth, number of cone rotations during the sample period, cone rotation time, amount and type of debris removed from the live box, basic weather conditions, water temperature, water velocity entering the cone, and turbidity. Water depths were measured to the nearest 0.03 m (0.1 feet) using a graduated staff. The cone fishing depth was measured with a gauge permanently mounted to the trap frame in front of the cone. The number of rotations of the RST cone was measured with a mechanical stroke counter (Reddington Counters, Inc., Windsor, CT) that was mounted to the trap railing adjacent to the cone. The amount of debris in the live box was volumetrically measured using a 44.0 liter (10-gallon) plastic tub. Water temperatures were continuously measured with an instream Onset Optic Stow Away® temperature data logger. Water velocity was measured as the average velocity from a grab-sample using an Oceanic® Model 2030 flowmeter (General Oceanics, Inc., Miami, Florida). The average velocity was measured for a minimum of 3 min while the live box was being cleared of debris. Water turbidity was measured from a grab-sample with a Hach® Model 2100 turbidity meter (Hach Company, Ames, Iowa). In addition, daily stream discharge data collected by the U.S. Geological Survey at the Coleman Hatchery gauging station (#11376550) was also used for trap operations and to compare discharge and downstream migration patterns. The gauge site is located below the Coleman Fish Hatchery barrier weir and approximately 0.2 km downstream of the UBC trap (Figure 1).

Biological Sampling

Juvenile sampling at the traps was conducted using standardized techniques that were generally consistent with the CVPIA's Comprehensive Assessment and Monitoring Program (CAMP) standard protocol (CVPIA 1997). Dip nets were used to transfer fish and debris from the live box to a sorting table for examination. Each day the trap was sampled, a minimum number of each fish taxa captured were counted and then depending on the species, either fork length (FL) or total length (TL) was measured. Mortalities were also counted and measured. Live fish to be measured were placed in a 3.8-L (1-gallon) plastic tub and anesthetized with a tricaine methanesulfonate (MS-222; Argent Chemical Laboratories, Inc. Redmond, Washington) solution at a concentration of 60 to 80 mg/L. After being measured, fish were placed in a 37.8-L (10-gallon) plastic tub filled with fresh water to allow for recovery before being released back into the creek. Water in the tubs was replaced as necessary to maintain adequate temperature and oxygen levels. Catch data for all fish taxa were typically summarized as either weekly totals for salmonids or season totals for non-salmonids. Due to the large numbers of juvenile salmon that were frequently encountered and project objectives, different criteria were used to sample salmon, trout, and non-salmonid species.

Chinook salmon.—When less than approximately 250 salmon were captured in the trap all salmon were counted and measured for FL (to the nearest 1 mm). The measured juvenile salmon were also assigned a life-stage classification of fry (C1), parr (C2), silvery parr (C3), or smolt (C4), and a run designation of fall, late-fall, winter, or spring. Life-stage classification was based on morphological features and run designations were based on length-at-date criteria from Greene (1992). Length data for all Chinook salmon runs was combined for graphical purposes as the length-at date criteria developed for the mainstem Sacramento River may not be directly applicable to the tributary populations.

When more than approximately 250 juvenile salmon were captured, subsampling was conducted. All salmon in the subsample were identified, counted, and measured. These salmon were also assigned a life-stage classification and run designation, using the methods described above. All other salmon were counted and identified. A cylinder-shaped net with 3-mm mesh and a split-bottom construction was used for subsampling. The bottom of the subsampling net was constructed with a metal frame that created two equal halves. A closed mesh bag was sewed onto one half of the frame and an open mesh bag was sewed onto the other half of the frame. The subsampling net was placed in a 117-L (30-gallon) bucket that was partially filled with creek water. All captured juvenile salmon were poured into the bucket. Once the fish had distributed evenly throughout the bucket, the net was lifted and approximately half of the salmon were retained in the side of the net with the closed mesh bag, and approximately half of the salmon in the side with the open mesh bag were retained in the bucket. We continued to successively subsample (split) until approximately 150 to 250 individuals remained in a subsample. The number of successive splits that we used varied with the number of salmon collected. Subsampling was used to obtain a representative sample for measuring. To determine total catch, we counted all salmon in each split. Chinook salmon biological data were summarized by brood year for each run designation.

Rainbow trout/steelhead.—Due to the smaller numbers encountered, all rainbow trout/steelhead captured in the traps were counted and FL measured to the nearest 1 mm. Life stages of juvenile trout were classified similarly as salmon, with the addition of a yolk-sac fry life stage, as requested by the Interagency Ecological Program (IEP) Steelhead Project Work Team. All live rainbow trout/steelhead > 50 mm captured at both traps were weighed to the nearest 0.1 g for CDFG's Stream Evaluation Program.

Non-salmonid taxa.—All non-salmonid taxa that were captured were counted, but we only measured up to approximately 30 randomly selected individuals for each taxa. Total length was measured for lamprey *Lampetra spp.,* sculpin *Cottus spp.*, and western mosquitofish (*Gambusia affinis*); otherwise, FL was measured for all other non-salmonid taxa. Non-salmonids were not the focus of this monitoring project, therefore only total catch by species is provided in this report but length data is available.

Trap Efficiency and Juvenile Salmonid Passage

One of the goals of our monitoring project was to estimate the number of juvenile salmonids passing downstream in a given unit of time, usually a week and brood year. We defined this estimate as the juvenile passage index (JPI). Since each trap only captures fish from a small portion of the creek cross section, we used trap efficiencies, which were determined using mark-recaptured methods, and the actual catch to estimate the weekly and annual JPI. For days when the trap was not fishing, daily catch was estimated by averaging an equal number of days before and after the days not fished. For example, if the trap did not fish for 2 d, the daily catch for those days was estimated by averaging catch from 2 d before and 2 d after the period the trap did not fish. However, if one of the days before or after was also a missed day, it was usually not used to estimate other missed days. For example, if the trap did not fish for 3 d, but one of the 3 days before was also a missed day, then catch from the 2 d before and 3 d after the missed period were used to estimate catch.

During the current reporting period, late-fall Chinook salmon released by the hatchery in December 2002 and January 2003 were all marked with an adipose fin clip; therefore, when they were captured in the trap, they were subtracted from the daily catch. In 2003 no fall Chinook salmon released by the hatchery were marked; therefore, during April when they were released, no Chinook salmon >45 mm were included in the LBC daily count. In late-May 2003, large numbers of Chinook salmon 72 to 110 mm in length were captured in the LBC trap. No known hatchery release was scheduled in May, but many fish exhibited fin erosion commonly seen in hatchery fish; therefore, to determine daily catch of naturally produced Chinook salmon, all salmon with obvious fish erosion were classified as hatchery fish and not included in the daily catch.

Mark-recapture trials.— Mark-recapture trials were conducted to estimate trap efficiency. Ideally, separate mark-recapture trials should be conducted for each species, run, and life-stage to estimate species and age-specific trap efficiencies. However, catch rates for steelhead, spring, winter, and late-fall Chinook salmon were too low to conduct separate trials; therefore, trap efficiencies were estimated using primarily fall Chinook salmon fry, but late-fall Chinook salmon fry and larger fish were used for a few trials. We attempted to use only naturally-produced (unmarked, unclipped, and untagged) juvenile salmon for mark-recapture trials. However, when trap catches were insufficient in March and April, some hatchery fish that were captured in the LBC trap were used for mark-recapture trials. Marked Chinook salmon that were recaptured in the traps were counted, measured, and subsequently released downstream of the trap to prevent them from being recaptured again.

During the 2002 to 2003 season, two marks were used during all but one trial conducted at the LBC trap (Table 2). To apply the first mark, juvenile salmon were immersed in Bismark brown-Y stain (J. T. Baker Chemical Company, Phillipsburg, New Jersey) for 50 min at a concentration of 8 g/380 L of water (211 mg/L). When air temperatures were high in late spring and summer, a portable water chiller unit was used to maintain ambient stream temperatures and reduce stress and mortality during the staining process. For the second mark, Bismark brown stained salmon were anesthetized with an MS-222 solution at a concentration of 60 to 80 mg/L. Once the Bismark brown stained fish were anesthetized, lower-caudal fin-clips were applied using scissors to remove a small portion of the lower caudal fin. Marked fish were placed in a live-car and allowed to recover. During the first trial only one mark (Bismark brown) was used, but no marked fish were recaptured because the trap was pulled due to high flows; therefore the trial results were not used. Two mark-recapture trials were conducted at the LBC trap during most weeks; however, when the numbers of salmon available for marking were low, only one trial was conducted each week. All salmon marked for LBC trials were released at the Jelly's Ferry Bridge which is located approximately 1.3 km (0.8 mi) upstream of the trap (Figure 1). Trials conducted at the UBC trap were done using methods similar to those used for the LBC trap (Bismark brown). During 16 of the 18 trials conducted at the UBC trap, an upper-caudal fin-clip was applied to allow field crews to differentiate between fish released for trials at the LBC trap (Table 3). Only one mark was used during the first trial, but no marked fish were recaptured because the trap was pulled due to high flows; therefore the trial results were not used. During the April 2 trial, salmon with both an upper or lower-caudal fin-clip were released because fish originally marked for an LBC trial were used for the UBC trial because we did not operate the LBC trap during the trial. During 6 weeks when fish were available, two mark-recapture trials were conducted each week at the UBC trap. However, when the numbers of salmon available for marking were low, only one trial was conducted each week. All fish marked for UBC trials were released at the Coleman National Fish Hatchery's Intake 3 located 1.6 km (1.0 mi) upstream of the UBC trap (Figure1). Although not presented in this report, we measured the fork length of about 50 marked salmon prior to release, and then measured all of the recaptured salmon to make comparisons between marked fish released and marked fish recaptured. Marked fish were generally held overnight and released the next day. Prior to release, mortalities and injured fish were removed and the remaining fish were counted and released. During most trials, marked fish were released after dark or at dusk to reduce the potential for unnaturally high predation on salmon that may be temporarily disorientated during transportation, and to simulate natural populations of outmigrating Chinook salmon which move downstream primarily at night (Healey 1998; J. T. Earley, USFWS, RBFWO, unpublished data).

Trap efficiency.—Trap efficiency was estimated using a stratified Bailey's estimator, which is a modification of the standard Lincoln-Peterson estimator (Bailey 1951; Steinhorst et al. 2004). The Bailey's estimator was used as it performs better with small sample sizes and is not undefined when there are zero recaptures (Carlson et al. 1998; Steinhorst et al. 2004). In addition, Steinhorst et al. (2004) found it to be the least biased of three estimators. Trap efficiency was estimated by

$$\hat{E}_h = \frac{(r_h + 1)}{(m_h + 1)}, \tag{1}$$

where m_h is the number of marked fish released in week h and r_h is the number of marked fish recaptured in week h. Although trap efficiency was calculated for all mark-recapture trials, only those trials with at least seven recaptures were used as suggested by Steinhorst et al. (2004). Occasionally if a mark-recapture trial had less than seven recaptures, but the estimated trap efficiency and the mean weekly stream flows were similar to adjacent week(s), the number of marks and recaptures were pooled prior to estimating trap efficiency. Otherwise, a season average efficiency was used to estimate the JPI during weeks where there were less than seven recaptures or during weeks when no mark-recapture trials were conducted. The season average efficiency was based on all trials with more than seven recaptures, unless there were trials that had been pooled, in which case the pooled results were used when calculating the season average efficiency. If two mark-recapture trials were conducted during the same week, the results were combined to calculate the average weekly trap efficiency. A half-cone modification used at the LBC trap for 3 d during a hatchery release did not influence the results of the mark-recapture because no salmon were captured during that week and no mark-recapture trials were conducted.

Juvenile passage index (JPI).— Weekly JPI estimates for Chinook salmon and rainbow trout/steelhead were calculated using weekly catch totals and either the weekly trap efficiency, pooled trap efficiency, or average season trap efficiency. Juvenile Chinook salmon JPI's at LBC and UBC were summarized by brood year where the weekly catch for each run of Chinook salmon included all life-stages from a single brood year. Rainbow trout/steelhead were summarized as either young-of-the-year (yoy) or age 1+, which included individuals from all other age classes The fork length distribution (fork length by date) of rainbow trout/steelhead captured in either trap was used to determine weekly catch of young-of-the-year and age 1+. With few exceptions, graphical display of fork length distribution indicated a distinct separation of the two groups. In addition, age 1+ and young-of-the-year rainbow trout/steelhead captured during the same week could usually be distinguished by their life-stage classification.

The season was stratified by week because as Steinhorst et al. (2004) found, combining the data where there are likely changes in trap efficiency throughout the season leads to biased estimates. Using methods described by Carlson et al. (1998) and Steinhorst et al. (2004), the weekly JPI's were estimated by

$$\hat{N}_h = \frac{U_h}{\hat{E}_h}, \tag{2}$$

where U_h is the unmarked catch during week h. The total JPI for the year is then estimated by

$$\hat{N} = \sum_{h=1}^{L} \hat{N}_h \tag{3}$$

where L is the total number of weeks. Variance and the 90 and 95% confidence intervals for $\hat{N}_h$ each week were determined by the percentile bootstrap method with 1,000 iterations (Efron and Tibshirani 1986; Buckland and Garthwaite 1991; Thedinga et al. 1994; Steinhorst et al. 2004). Using simulated data with known numbers of migrants, and trap efficiencies, Steinhorst et al. (2004) determined the percentile bootstrap method for developing confidence intervals performed the best, as it had the best coverage of a 95% confidence interval. Each bootstrap iteration involved first drawing 1,000 r^*_{hj} (j=1, 2…, 1000; asterisk indicates bootstrap simulated values) from the binomial distribution (m_h, $\hat{E}_h$)(Carlson et al. 1998) and then calculating 1,000 $\hat{N}^*_{hj}$ using equations (1) and (2), replacing r_h with r^*_{hj}. The 1,000 bootstrap iterations of the total JPI ($\hat{N}^*_j$) were calculated as

$$\hat{N}^*_j = \sum_{h=1}^{L} \hat{N}^*_{hj} . \tag{4}$$

As described by Steinhorst et al. (2004), the 95% confidence intervals for the weekly and total JPI's were found by ordering the 1,000 $\hat{N}^*_{hj}$ or $\hat{N}^*_j$ and locating the 25th and 975th values. Similarly, the 90% confidence intervals for the weekly and total JPI's were found by locating the 50th and 950th values of the ordered iterations. Ordering was not performed until after the $\hat{N}^*_j$ were derived. The variances for $\hat{N}_h$ and $\hat{N}$ were calculated as the standard sample variances of the 1,000 $\hat{N}^*_{hj}$ and $\hat{N}^*_j$, respectively (Buckland and Garthwaite 1991).

Results

Trap Operation

Lower Battle Creek (LBC).— During the current reporting period, the LBC trap was operated continuously from October 1, 2002 to July 29, 2003, except during high flows, hatchery releases, periods of reduced sampling, etc (Appendix 1). Of the 302 d available, the trap was operated 217 d. Reduced sampling due to limited staff accounted for 35 of the missed sample days (41%), high flows accounted for 18 d (21%), hatchery releases accounted for 16 d (19%), and other miscellaneous reasons and holidays accounted for the remaining 16 d (19%). Monthly sampling effort from October 2002 through July 2003 varied from a low of 50% in April to a high of 97% in October (Figure 2). The trap was not operated from July 30 to September 30, 2003 because sampling from previous years has shown that little or no salmonid outmigration occurs during that time (Whitton et al. 2006, Whitton et al. 2007).

Mean daily water temperatures at the LBC trap varied from a low of 6.3ºC (43.4 ºF) on December 23, 2002 to a high of 21.7ºC (71.0 ºF) on July 23, 2003 (Figure 3). Mean daily flow that was measured by the U.S. Geological Survey at the Coleman Hatchery gauging station (#11376550) varied from lows of 5.9 m^3/s (210 cfs) in October 2002 to a peak flow of 94.6 m^3/s on January 14, 2003 (3,340 cfs; Figure 3). Turbidity at the LBC trap varied from lows <1.0 for several days in October and November to a peak of 12.6 NTU's on April 12, 2003 (Figure 3). In general, turbidity increased with increasing flows, but increases in turbidity did not always appear to be related to similar increases in flow (Figure 3). However, turbidity was only measured when the trap was operated.

Upper Battle Creek (UBC).—During the current reporting period, the UBC trap was operated continuously from October 10, 2002 to August 18, 2003, except during high flows, periods of reduced sampling, and other days for miscellaneous reasons (Appendix 2). Of the 322 d available, the trap was operated 247 d. Reduced sampling due to limited staff accounted for 45 of the missed sample days (60%), high flows accounted for 16 d (21%), and other miscellaneous reasons and holidays accounted for 3 d (4%). In addition, the trap was not operated for 11 days (15%) in late-July to early-August, likely because no salmonids were captured after July 14, 2003. The monthly sampling effort from October 2002 through August 2003 varied from a low of 29% in August to a high of 100% in October and November (Figure 2; Appendix 2). The trap was not operated from August 19 to September 30, 2003 because sampling from previous years has shown that little or no salmonid outmigration occurs during that time (Whitton et al. 2006, Whitton et al. 2007).

Mean daily water temperatures at the UBC trap varied from a low of 6.3 ºC (43.3 ºF) on December 21, 2002 to a high of 20.4ºC (68.7 ºF) on July 23 and 30, 2003 (Figure 4). Mean daily flows for the UBC trap are the same as those reported for LBC as the same gauging station was used (Figure 4). Turbidity at the UBC trap varied from several days <1.0 NTU's in October and November 2002 and July 2003 to a high of 12.6 NTU's on November 9, 2002 (Figure 4). In general, turbidity increased with increasing flows, but increases in turbidity did not always appear to be related to similar increases in flow (Figure 4). However, turbidity was only measured when the trap was operated.

Biological Sampling

Spring Chinook salmon-LBC.—Brood year 2002 (BY02) spring Chinook salmon were first captured at the LBC trap the week of December 16, 2002 with a peak weekly catch of 100 the week of March 24, 2003 (Table 4 and Figure 5). There was an earlier smaller peak of 26 the week of December 23, 2002. These two peaks represent the initial movement of fry out in December, and then larger fish (parr, silvery parr, and smolt) in March through May. The last spring Chinook salmon was captured the week of June 2, 2003. The BY02 spring Chinook salmon total catch based on the length-at-date criteria was 181. However after adjusting the total catch for days the trap was not operated, the adjusted total catch was 301.

Fork lengths of spring Chinook salmon sampled at the LBC trap varied from 39 to 127 mm with a mean of 79 mm (Figure 6). Length frequency data for all runs were combined because run designations were determined using length-at-date-criteria developed for the Sacramento River (Green 1992; Figure 7). In Battle Creek, there is overlap in fork lengths between runs, but the overlap appears to be a particular problem with spring and fall Chinook salmon. The life-stage composition of spring Chinook salmon captured at the LBC trap was 5.6% fry, 23.4% parr, 44.7% silvery parr, and 26.3% smolt (Table 1).

Fall Chinook salmon - LBC.—Fall Chinook salmon were the most abundant salmonid captured at the LBC trap. Brood year 2002 fall Chinook salmon were first captured at the trap the week of December 9, 2002 (Table 5 and Figure 5). Following their initial capture, the numbers of fall Chinook salmon increased rapidly to a peak weekly capture of 13,991 the week of February 10, 2003. A second smaller peak weekly catch of 735 occurred the week of May 19, 2003. The total number of BY02 fall Chinook salmon captured in the LBC trap on days that it was operated was 59,870. After adjusting the total catch reported above for days the trap was not operated, the adjusted total catch of BY02 fall Chinook salmon at the LBC trap was 67,932.

Fall Chinook salmon fork lengths ranged from 25 to 106 mm during the reporting period, with a mean fork length of 42 mm (Figure 6). Length frequency data for all runs were combined because run designation was determined by length-at-date-criteria developed for the Sacramento River (Green 1992; Figure 7). Length frequency histograms for Chinook salmon were highly skewed towards newly emerging fry ≤40 mm (80%; Figure 7). Fall Chinook salmon fry comprised the largest portion of these fish as they were the most abundant run captured at the LBC trap. All four life-stages of fall Chinook salmon were captured during the reporting period (Table 1). Fry were 79.8% of the fall Chinook salmon sampled at the trap, parr were 9.7%, silvery parr 9.8%, and smolt 0.7%.

Late-fall Chinook salmon - LBC.— Individuals from two brood years of late-fall Chinook salmon (BY02 and BY03) were captured at the LBC trap between October 1, 2002 and September 30, 2003; however, only 26 BY02 late-fall Chinook salmon were captured in the trap during the reporting period (Table 6 and Figure 5). Brood year 2002 late-fall Chinook salmon weekly and annual passage estimates were reported in the 2001-2002 report (Whitton et al. 2007). Brood year 2003 late-fall Chinook salmon were first captured in the trap the week of March 24, 2003 with a peak weekly capture of 666 the week of April 28, 2003 (Table 7 and Figure 5). The last week of capture was November 24, 2003. Data from the next reporting period (October 1 to December 24, 2003) was used to allow complete reporting of BY03 late-fall Chinook salmon catch and passage estimates. Using length-at-date criteria, the actual catch of BY03 late-fall Chinook salmon in the LBC trap was 2,146. After adjusting total catch for days the trap was not operated, the adjusted total catch of BY03 late-fall Chinook salmon was 3,883.

Fork lengths of late-fall Chinook salmon captured at the LBC trap varied from 30 to 127 mm with a mean fork length of 37 mm (Figure 6). Length frequency histograms which included all runs of Chinook salmon were highly skewed towards newly emerging fry ≤40 mm (Figure 7). The life-stage composition of late-fall Chinook salmon sampled at the LBC trap was 91.9% fry, 6.8% parr, 0.8% silvery parr, and 0.5% smolt (Table 1).

Winter Chinook salmon - LBC.—Winter Chinook salmon were first captured at the LBC trap the week of October 14, 2002 with the peak weekly catch of 30 occurring the same week (Figure 5). The last day winter Chinook were captured at the trap was July 15, 2003. Winter Chinook are likely migrants from the Sacramento River using lower Battle Creek for non-natal rearing. The total catch based on the length-at-date criteria was 79. However after adjusting the total catch for days the trap was not operated, the adjusted total catch was 104.

Fork lengths of winter Chinook salmon sampled at the LBC trap varied from 31 to 185 mm with a mean of 64 mm (Figure 6). Fork length frequency data for winter Chinook salmon was combined with other runs for graphical display (Figure 7). The life-stage composition of winter Chinook salmon sampled at the trap was 7.7% fry, 33.3% parr, 51.3% silvery parr, and 7.7% smolt (Table 1). Winter Chinook salmon use lower Battle Creek for non-natal rearing which likely accounts for the limited presence of the fry life-stage.

Rainbow trout/steelhead - LBC.— During the reporting period 75 age 1+ and 290 young-of-the-year (yoy) rainbow trout/steelhead were captured at the LBC trap. Rainbow trout/ steelhead were first captured at the LBC trap the week of October 7, 2002 with a peak weekly capture of 49 occurring the week of May 19, 2003 (Table 7 and Figure 8). The actual rainbow trout catch at the LBC trap was 223; however, after adjusting the total catch for days the trap was not operated, the adjusted total catch was 365.

Fork lengths of age 1+ trout ranged from 58 to 490 mm with a mean and median of 171 mm and 168 mm, respectively (Figure 9 and 10). Fork lengths of young-of-the-year (yoy) rainbow trout/steelhead ranged from 21 to 154 mm with a mean and median of 66 mm (Figure 9 and 10). The range in fork lengths of yoy trout accounts for growth over time. The length frequency histogram for trout was not skewed towards newly emerging fry ≤30 mm as seen in previous years, rather 60% of all trout captured were 50 to 90 mm in length (Figure 10). Rainbow trout/steelhead parr (70.6%), fry (12.1%), and silvery parr (10.3%) were the most abundant life-stages sampled at the LBC trap, while yolk-sac fry and smolt were the least abundant (0.5 and 6.5%; Table 1).

Non salmonids - LBC.—From October 1, 2002 through July 29, 2003, 10 native non-salmonid species were sampled at the LBC trap including, California roach *Hesperoleucus symmetricus* (N=3), speckled dace *Rhinicthys osculus* (N=35), hardhead *Mylopharodon conocephalus* (N=2,630), Pacific lamprey *Lampetra tridentata* (N=40), prickly sculpin *Cottus asper* (N=10), riffle sculpin *Cottus gulosus* (N=40), Sacramento pikeminnow *Ptychocheilus grandis* (N=369), Sacramento sucker *Catostomus occidentalis* (N=149), tule perch *Hysterocarpus traski* (N=158), and threespine stickleback *Gasterosteus* aculeatus (N=29). In addition, three introduced non-salmonids were also captured in the LBC trap including, green sunfish *Lepomis cyanellus* (N=15), largemouth bass *Micropterus salmoides* (N=387), and western mosquitofish *Gambusia affinis* (N=143). Next to Chinook salmon, hardheads were the next most abundant species captured in the traps. In addition, several unidentified cottid, cyprinid, centrarcid, and lamprey fry were also captured in the trap and 12 "eyed" Lamprey were captured at the trap, but were not identified to species.

Spring Chinook salmon - UBC.— Brood year 2002 spring Chinook salmon were first captured at the UBC trap the week of December 9, 2002 with a peak weekly catch of six the weeks of April 21 and 28, 2003 (Table 8 and Figure 11). The last BY02 spring Chinook salmon was captured the week of May 26, 2003. The BY02 spring Chinook salmon total catch based on the length-at-date criteria was 31. However after adjusting the total catch for days the trap was not operated, the adjusted total catch was 47.

The fork length of spring Chinook salmon sampled at the trap varied from 36 to 114 mm with a mean and median fork length of 86 and 91 mm, respectively (N=31; Figure 12). Length frequency for all runs was combined because run designation was determined by the length-at-date-criteria developed for the Sacramento River, and there is overlap between runs, particularly between spring and fall Chinook salmon (Green 1992; Figure 13). The life-stage composition of spring Chinook salmon sampled at the UBC trap was 12.9% fry, 9.7% parr, 25.8% silvery parr, and 51.6% smolt (Table 1).

Fall Chinook salmon - UBC.—Fall Chinook salmon were the most abundant salmonid captured at the UBC trap. Brood year 2002 fall Chinook salmon were first captured in the trap the week of December 2, 2002 with the peak weekly catch of 284 occurring the week of December 30, 2002 (Table 9 and Figure 11). Following their initial capture, the numbers of fall Chinook salmon increased rapidly and were captured every week until the week of June 23, 2003. The total number of BY02 fall Chinook salmon captured in the UBC trap on days that it was operated was 686. After adjusting the total catch reported above for days the trap was not operated, the adjusted total catch of BY02 fall Chinook salmon at the UBC trap was 977.

Fork lengths of fall Chinook salmon sampled at the UBC trap varied from 31 to 96 mm with a mean of 40 mm (N=686; Figures 12 and 13). Length frequency histograms for Chinook salmon were highly skewed towards newly emerging fry ≤40 mm (86%; Figure 13). Fall Chinook salmon fry comprised the largest portion of these fish as they were the most abundant run of Chinook salmon captured at the UBC trap. The life stage composition of fall Chinook salmon sampled at the UBC trap was 86.7% fry, 1.9% parr, 9.0% silvery parr, and 2.3% smolt (Table 1).

Late-fall Chinook salmon - UBC.— Individuals from two brood years of late-fall Chinook salmon (BY02 and BY03) were captured at the UBC trap between October 10, 2002 and December 31, 2003; however, only one BY02 late-fall Chinook salmon was captured during the reporting period (Figure 11). Brood year 2003 late-fall Chinook were first captured in the trap the week of April 14, 2002 with a peak weekly capture of 102 the week of June 9, 2003 (Table 10 and Figure 11). The last week a BY03 late-fall Chinook salmon was captured was December 22, 2003. Data from the next reporting period (October 1, 2003 to December 31, 2003) was used to allow complete reporting of BY03 late-fall Chinook salmon catch and passage estimates. Five additional late-fall Chinook salmon were captured between October 1 and December 31, 2003. Using length-at-date criteria, the BY03 late-fall Chinook salmon total catch was 259. After adjusting the total catch for days the trap was not operated, the adjusted total catch of BY03 late-fall Chinook salmon was 357.

Fork lengths of late-fall Chinook salmon captured at the UBC trap varied from 32 to 114 mm with a mean fork length of 35 mm (Figure 12). Length frequency histograms which included all runs of Chinook salmon were highly skewed towards newly emerging fry ≤40 mm (Figure 13). During the current reporting period, the life-stage composition of BY03 late-fall Chinook salmon sampled at the UBC trap was 100% fry (Table 1).

Winter Chinook salmon - UBC.—During the reporting period, only two winter Chinook salmon were captured in the UBC trap; therefore, no additional information will be reported for this race (Figure 12).

Rainbow trout/steelhead - UBC.— During the reporting period 31 age 1+ and 368 young-of-the-year (yoy) rainbow trout/steelhead were captured at the UBC trap. They were first captured the week of November 4, 2002 with a peak weekly capture of 49 occurring the week of May 19, 2003 (Table 11 and Figure 14). The actual rainbow trout catch at the UBC trap was

261; however, after adjusting the total catch for days the trap was not operated, the adjusted total catch was 399.

Fork lengths of age 1+ trout ranged from 90 to 239 mm with a mean of 159 mm and a median of 148 mm (Figure 15 & 16). Fork lengths of young-of-the-year (yoy) rainbow trout/steelhead ranged from 20 to 121 mm with a mean of 61 mm and a median of 63 mm (Figures 15 and 16). The range in fork lengths of yoy trout accounts for growth over time. The length frequency histogram for trout was not skewed towards newly emerging fry ≤30 mm as seen in previous years, rather 58% of all trout captured were 50 to 90 mm in length (Figure 16). Rainbow trout/steelhead fry (24.5%) and parr (65.8%) were the most abundant life-stages sampled at the UBC trap, whereas silvery parr, smolt, and yolk-sac fry were the least abundant (7.0, 1.9, and 0.8%; Table 1).

Non salmonids - UBC.— From October 10, 2002 through August 18, 2003, 10 native non-salmonid species were captured in the UBC trap, including California roach (N=1), speckled dace (N=2), hardhead (N=454), Pacific lamprey (N=17), prickly sculpin (N=2), riffle sculpin (N=41), Sacramento pikeminnow (N=129), Sacramento sucker (N=246), tule perch (N=12), and threespine stickleback (N=62). In addition, two introduced non-salmonid species were captured, including green sunfish (N=1) and smallmouth bass *Micropterus dolomieu* (N=1). Lamprey, cyprinid, and cottid fry were also captured at the trap, but could not be identified to species. Besides Chinook salmon, lamprey fry were the most abundant group of fish captured at the trap (N=1,236). Hardheads and Sacramento suckers were the most abundant non-salmonid species captured in the UBC trap

Trap Efficiency and Juvenile Salmonid Passage

Lower Battle Creek trap efficiency (LBC).—To estimate trap efficiency, 18 mark-recapture trials were conducted at the LBC trap (Table 2). We marked Chinook salmon during 12 of the 44 weeks that salmonids were captured at the LBC trap (October 1, 2002 through July 28, 2003). The results of three trials were not used to calculate passage because one had no recaptures (January 22, 2003) because high flows forced us to pull the trap after the fish were released, and two trials (March 26 and May 20, 2003) had less than seven recaptures and the results could not be pooled with trials from an adjacent week. Of the 15 trials that were used to calculate passage, 14 had at least seven recaptures as recommended by Steinhorst et al. (2004). One trial with less than seven recaptures was one of two trials conducted during the same week; therefore, the results were pooled with the other trial conducted that week. During six of the weeks that trials were conducted, two separate mark-recapture trials were conducted and the results were pooled prior to calculating the weekly passage. During the remaining six weeks, only one trial was conducted. Weekly trap efficiencies for the valid pooled and unpooled trials varied from 0.073 to 0.242. Using the results of these trials, the season average efficiency was estimated at 0.132. The 2002 to 2003 season average efficiency was used to estimate passage for 35 weeks during October 1, 2002 to September 30, 2003 when no trials were conducted or when trials results were not used.

Upper Battle Creek trap efficiency (UBC).—To estimate trap efficiency, 20 mark-recapture trials were conducted at the UBC trap (Table 3). We marked Chinook salmon during 13 of the 37 weeks that salmonids were captured at the UBC trap (November 4, 2002 through July 21, 2003). The results of four trials were not used to calculate passage because two had no recaptures (January 22 and February 3, 2003) and two had less than seven recaptures and the results could not be pooled with trials from and adjacent week (March 20 and 26, 2003). Of the 16 trials that were used to calculate passage, 13 had at least seven recaptures as recommended by

Steinhorst et al. (2004). Two trials with less than seven recaptures were pooled with each other as they were conducted during adjacent weeks and efficiencies and mean flows were similar (April 2 and 9, 2003). One trial with less than seven recaptures was one of two trials conducted during the same week (February 17, 2003); therefore, the results were pooled with the other trial conducted that week. During six of the weeks that trials were conducted, two separate mark-recapture trials were conducted and the results were pooled prior to calculating the weekly passage. During all other weeks, either one or no trial was conducted. Weekly trap efficiencies for valid pooled and unpooled trials varied from 0.031 to 0.082. Using the results of these trials, the season average efficiency was estimated at 0.054. The 2002 to 2003 UBC season average trap efficiency was used to estimate passage for 24 weeks during November 4, 2002 through July 21, 2003 when no trials were conducted or when trials results were not used.

Lower Battle Creek juvenile salmonid passage (LBC).—At the LBC trap, trap efficiency estimates were used to generate juvenile passage indexes (JPI) for spring, fall, and late-fall Chinook salmon and rainbow trout/steelhead. Although juvenile passage indexes were calculated for spring Chinook salmon, they are an underestimate because of the overlap in length with fall Chinook salmon. Juvenile passage index estimates were not calculated for winter Chinook salmon as they are likely migrants from the Sacramento River using lower Battle Creek as non-natal rearing habitat.

The annual JPI for BY02 spring Chinook salmon was 2,383 and the 90 and 95% confidence intervals were 2,143 to 2,694 and 2,110 to 2,791, respectively (Table 4). A peak weekly passage of 758 occurred the week of March 24, 2003 although a smaller peak of 197 occurred earlier, the week of December 23, 2002. These two peaks represent the initial movement of fry out in December, and then larger fish (parr, silvery parr, and smolt) in March and April. The annual JPI for BY02 fall Chinook salmon was 581,677 (Table 5). The 90 and 95% confidence intervals for the annual JPI were 542,513 to 625,834 and 537,926 to 636,193, respectively. The weekly JPI's for fall Chinook salmon increased rapidly to a peak of 131,845 the week of February 10, 2003 and then began to decrease until early May when passage increased for a short time. The annual JPI for BY03 late-fall Chinook salmon was 31,538 (Table 6). The 90 and 95% confidence intervals for the annual JPI were 29,371 to 34,089 and 29,126 to 34,580, respectively. The weekly JPI's for late-fall Chinook salmon increased quickly to a peak of 5,045 the week of April 28, 2003, and then decreased to <1,000 12 weeks after the start of the outmigration; however, a few additional fish were captured sporadically until early-December. Passage estimates for BY02 late-fall Chinook salmon are not reported here because only a small portion of the run was sampled during the current reporting period. Rather, passage estimates for BY02 late-fall Chinook salmon were summarized in the 2001-2002 report (Whitton et al. 2007). The annual JPI for yoy rainbow trout/steelhead passing the LBC trap between September 30, 2002 and September 30, 2003 was 2,313 while passage for age1+ fish was 577 (Table 7). The 90 and 95% confidence intervals for the yoy annual JPI estimate were 2,164 to 2,479 and 2,187 to 2,520, respectively. The 90 and 95% confidence intervals for the annual JPI for age 1+ fish were 540 to 622 and 533 to 632, respectively. Most age 1+ fish migrated between October and early June with a peak weekly passage the week of December 16, 2002 (N=159). In contrast, yoy were not captured in the trap until mid-February with a peak weekly passage of 356 the week of May 19, 2003.

Upper Battle Creek juvenile salmonid passage (UBC).—At the UBC trap, trap efficiency estimates were used to generate juvenile passage indexes (JPI) for spring, fall, and late-fall Chinook salmon and rainbow trout/steelhead. Although juvenile passage indexes were calculated for spring Chinook, they are an underestimate because of the overlap in length with fall Chinook salmon and small sample sizes. Juvenile passage indexes were not calculated for winter Chinook salmon because only two were captured in the trap.

The annual JPI for BY02 spring Chinook salmon was 955, and the 90 and 95% confidence intervals were 833 to 1,114 and 819 to 1,152, respectively (Table 8). A peak weekly passage of 173 occurred the week of April 21, 2003. The annual JPI for BY02 fall Chinook salmon at the UBC trap was 17,783, and the 90 and 95% confidence intervals were 15,899 to 19,779 and 15,661 to 20,247, respectively (Table 9). The weekly JPI's for fall Chinook salmon increased rapidly to a peak of 5,270 the week of January 13, 2003 and then decreased until early-March when passage began increasing slowly to a second peak (n=705) the week of May 19, 2003. The annual JPI for BY03 late-fall Chinook salmon was 6,702 and the 90 and 95% confidence intervals for the were 5,865 to 7,442 and 5,734 to 7,677, respectively (Table 10). The weekly JPI's for late-fall Chinook salmon increased quickly to a peak of 1,188 the week of May 5, 2003, and then decreased until early-June when passage increased to a second larger peak of 1,893 the week of June 9, 2003. Five additional late-fall Chinook salmon were captured from October 1 to December 31, 2003. No passage estimates were made for BY01 late-fall Chinook salmon captured at the UBC trap because only a small portion of the run was sampled during the current reporting period. Weekly and annual passage estimates for BY02 late-fall Chinook salmon at the UBC trap were summarized in the 2001-2002 report (Whitton et al. 2007). The annual JPI for yoy rainbow trout/steelhead passing the UBC trap between October 1, 2002 and September 30, 2003 was 7,145 whereas passage for age1+ fish was 592 (Table 11). The 90 and 95% confidence intervals for the yoy annual JPI estimate were 6,483 to 7,839 and 6,383 to 8,059, and the 90 and 95% confidence intervals for the annual JPI for age 1+ fish were 522 to 671 and 511 to 698, respectively. Most age 1+ fish migrated during November through May with a peak passage of 103 the week of March 31, whereas yoy were not captured in the trap until early-March with a peak weekly passage of 891 the week of May 19, 2003.

Discussion

Trap Operation

Staff shortages, hatchery releases, high flows, etc., limited our ability to operate either trap continuously during the sample season. In addition, neither trap was operated during most or all of August and September. However, sampling in previous years had shown that operating the traps during this period was not necessary because catch of Chinook salmon and rainbow trout/steelhead, which were the focus of our monitoring project, was very low to zero from July through October (Whitton et al. 2006, Whitton et al. 2007). Staff shortages during late March through June required us to operate the traps on a reduced schedule (4-5 d each week); therefore, we had to estimate salmonid catch on several missed days. In addition, to prevent potential mortality of naturally produced Chinook salmon from overcrowding, we did not operate the trap during hatchery releases of fall Chinook salmon upstream of the LBC trap; therefore, we had to estimate catch for additional days in April. During the reporting period, high flows prevented us from operating traps for 18 d at LBC and 16 d at the UBC. Most of the high flow events occurred during the peak fall and spring Chinook salmon fry outmigration period (December through February); therefore, we may have underestimated catch on days missed during high flow events because fry often disperse downstream during high flow events (Healey 1991). A few high flow events also occurred during the second fall and spring Chinook salmon outmigration peak that occurs from March to May. Other miscellaneous reasons which required us to estimate daily catch included, holidays, no cone rotation due to low flows or debris, etc., but the number of days estimated was limited to brief periods of time throughout the sample period. Estimating catch on missed days may affect our weekly and annual JPI's but the magnitude of the affect may vary with time of the year, catch, and number of consecutive days estimated. For instance, at the LBC trap we estimated catch for 37% of the days during March through June, and at the UBC trap we estimated catch for 30% of the days during March through June (Appendices 1 and 2). Estimating catch for several days may have been more problematic in April and May because sampling in prior years had shown that a secondary peak of larger fall and spring Chinook salmon (parr, silvery parr, and smolt) occurs during this time as well as the initial peak of late-fall Chinook salmon fry.

Determining whether there are better methods for estimating catch for days the traps are not operational may improve the accuracy of our passage estimates. Currently, average catch for an equal number of days before and after a period of missed sampling is used to estimate catch when the traps are not sampling. The accuracy of this method as well as others such as catch per unit volume (CPUV) or effort (CPUE) should be tested to determine whether there is a particular method that is more accurate at estimating catch during high-flow periods and other days the traps are not operated. The CPUE methodology has been used in a few other rotary screw trap studies to estimate passage during periods when traps were not operated (Griffith et al. 2001; Volkhardt et al. 2005), but comparisons with other methods did not occur.

> ***Recommendation:*** *Investigate the use of CPUV, CPUE, or other methods to estimate catch for days the trap is not fished.*

Biological Sampling

To effectively estimate passage and describe the biological characteristics of all races of Chinook salmon on Battle Creek, the sampling methods used at the traps must be tested to ensure their applicability and accuracy. Currently, length-at-date criteria (Greene1992) are used on Battle Creek to differentiate runs of juvenile Chinook salmon captured in the traps. However, the criteria were developed for the mainstem Sacramento River, and are not accurate for tributary runs of Chinook salmon. There is significant size overlap between runs, particularly fall and spring Chinook salmon. This discrepancy is important when trying to accurately estimate the passage of threatened and endangered Chinook salmon. The inaccurate run-designation likely resulted in underestimates of spring and overestimates of fall Chinook salmon passage at both traps. Considering the size overlap between runs, genetic sampling is likely the most accurate method for assigning a run designation. However, it is expensive and will likely only be done on a portion of the total catch, which then requires the results to be extrapolated to the total catch. Also, current genetic techniques for run identification of Central Valley Chinook may need to be verified or refined for application specifically to Battle Creek populations.

Subsampling was used to obtain a representative sample of Chinook salmon for measuring and estimating the length frequency distribution, but fish size or the abundance of uncommon runs may influence the accuracy of this method. Often only a few large Chinook salmon or those classified as spring and winter Chinook salmon were captured in the traps when fry or other runs were very abundant. Run designation for Chinook salmon included in our subsample was assigned using the length-at-date criteria (Greene 1992). This information was then extrapolated to the unmeasured fish to determine total daily catch for each run. This may have been problematic with larger fish or uncommon runs (spring and winter), because if none were included in the subsample, then they were not represented in the final catch totals for that day. However, if they were included in the subsample and then extrapolated to the unmeasured catch, the catch of larger fish and uncommon runs may have been artificially inflated. Inaccuracies due to subsampling only occurred at the LBC trap because subsampling did not occur at the UBC trap because catch was always less than 250. Ideally some days they would be under represented, and other days over represented resulting in an accurate overall estimate, but whether this occurs has not been determined and should be investigated.

> ***Recommendation**: Develop or utilize methods such as genetics for determining the run designation of Chinook salmon captured in the traps.*

Trap Efficiency and Juvenile Salmonid Passage

Trap efficiency.—Mark-recapture methods are commonly used to estimate trap efficiency, but the results are influenced by many factors, including flow, fish size and species, release time and location, predation, type of mark, etc. In 2002 to 2003, we conducted mark-recapture trials at various flows, and a moderate but significant inverse relationship was found between flow and trap efficiency at the LBC trap (R^2=0.52; P<0.01), but no relationship was found at the UBC trap (R^2=0.14; P=0.126). Trap location as well as other environmental and biological factors may determine how much influence flow has on trap efficiency. Fish size can influence capture efficiency, and ideally we should have conducted separate trials for each species, run, and life stage at various seasons and flows. However, our ability to conduct age, run, and species specific trials was limited by the low abundance of fish available within each category; therefore we used fall Chinook salmon fry and parr as surrogates. The applicability of our estimates to these other groups is questionable, but Roper and Scarnecchia (1996) found that behavioral differences between hatchery and naturally produced Chinook salmon were minimal when traps were operated in higher velocities. They compared trap efficiencies when a 2.43-m (8-ft) diameter trap was rotating an average of 3.05 rotations/min, 2.37 rotations/ min, and 1.40 rotations/min. During the current reporting period, our 1.5-m (5-ft) diameter traps usually rotated an average of 3 to 12 rotations/min or higher, unless there was algae build-up or debris plugging the cone, or during very low flows. It seems possible that at higher velocities the benefits of increased swimming ability found in larger fish may also be smaller. Chapman and Bjornn (1969) and Everest and Chapman (1972) found that fish size was positively correlated with water velocity and depth; therefore, it is possible that trap efficiencies may be higher for larger fish because they are more likely to be found in deeper faster water where our traps are fishing. While release location and time may have influenced trap efficiency measurements; the influences of release location and time should be similar for all trials since all marked fish were released from the same location and with a few exceptions, all fish were released at dusk or after dark.

The accuracy of our passage estimates was likely impacted by our inability to conduct mark-recapture trials at certain times of the year. We only conducted mark-recapture trials from January to May because insufficient numbers of naturally produced fall Chinook salmon fry and parr were available at other times of the year. The influences on our weekly JPI's were likely small at certain times of the year when catch was low, but, at other times it had a greater influence. For instance, the peak passage of spring Chinook salmon fry normally occurs in December, but to limit our impacts to a federally listed species, we did not conduct mark-recapture trials at that time.

We used two methods for dealing with weeks when mark-recapture trials were not conducted or when recapture rates were low (<7). First, if the trap efficiency and mean weekly flow of an adjacent week or weeks were similar, we pooled the results of the mark-recapture trials. Otherwise, we used a season average efficiency based on all valid trials to estimate passage. The accuracy of our estimates was likely affected by the use of either method; however, the magnitude of the effect depends on the estimated catch at the time it was used and how different the efficiency used to estimate production (pooled or season average) was from the true trap efficiency. The influences from pooling on the annual JPI estimates at the LBC trap was likely minimal compared to using a season average efficiency, as pooling was only done for trials conducted during the same week. At the UBC trap pooling between trials from adjacent weeks was done once in addition to pooling trials conducted during the same week. Using the season average efficiency likely had more influence on the annual JPI's at both traps because it was used for all weeks when trials were not conducted. The accuracy of weekly and annual passage estimates could be in question when using this method, particularly during weeks when large numbers of Chinook salmon were passing the trap. In future sampling, release groups for mark-recapture trials should be large enough to ensure a minimum of seven recaptures. This will eliminate the need to pool data from adjacent weeks improving the accuracy of our estimates. The affects from pooling trials conducted during the same week should also be investigated. In addition larger groups of marked fish will reduce the width of our confidence intervals.

In future trap operations, mark-recapture trials should be conducted for all weeks when sufficient numbers are available. The use of hatchery fish is being explored for future sampling. If hatchery fish are available, paired trials with naturally produced Chinook salmon should be done to test whether behavioral differences exist at all sizes. Hatchery fish have been used in some studies, but Roper and Scarnecchia (1996) found that trap efficiencies for hatchery and natural Chinook salmon were different because of differences in behavior. However, they also found that efficiencies for hatchery and natural Chinook were similar for a trap operated in relatively high velocities. Differences in behavior may be small when hatchery fry are used as surrogates for naturally produced fry. The use of hatchery fry would allow us to conduct trials during the peak spring Chinook salmon outmigration when flows are more variable.

Ideally, daily mark-recapture trials provide the most accurate estimates of trap efficiency (Roper and Scarnecchia 1999), however, they are also very time intensive and expensive. However, insufficient numbers of fish were available during most of the season, but when possible two trials were conducted per week. The results of these trials were combined to estimate a weekly efficiency. This method has been used by others such as Thedinga et al. (1994). One advantage of this method is that variations in flow which may affect trap efficiency during the week are accounted for with a weekly estimate. This method also ensures that sufficient recaptures occur to meet the minimum of seven as was recommended by Steinhorst et al. (2004). As occurred with our study, mark-recapture release strategies can vary and the affects on the final estimates needs to be studied further to determine the most effective and efficient method for providing reasonable statistically-sound estimates of trap efficiency. Some studies have developed flow-trap efficiency models to allow the estimation of daily trap efficiencies (Martin et al. 2001). This method appears to be valid, but may not be applicable to all streams. The flow to trap efficiency relationship needs to be sufficiently strong to ensure that estimates of efficiency are accurate. Other variables besides flow should also be considered.

> ***Recommendation***: *Investigate methods for conducting mark-recapture trials that will improve the accuracy of trap efficiency estimates such as: (a) conducting robust day and nighttime trials and applying the results to day and nighttime catch, (b) increasing the size of release groups during periods when trap efficiencies are likely to be low (i.e., high flows), (c) marking Chinook salmon so*

that fish from a particular trial are distinguishable from other trials, and (d) testing the effect of trial frequency on weekly passage estimates.

Recommendation: *Investigate the differences in capture efficiency of hatchery and naturally produced Chinook salmon at various life-stages. The ability to use hatchery fish at times when insufficient naturally produced fish are available would reduce the need to use the average season efficiency.*

Juvenile salmonid passage.—Passage of juvenile spring, fall, and late-fall Chinook salmon were lower at the LBC trap, and fall and late-fall Chinook salmon at the UBC trap were lower than seen in previous years (Tables 12 and 13). Based on non-overlapping 95% confidence intervals, statistically significant differences include; (1) the BY02 spring Chinook salmon annual JPI (2,315) was lower than the BY01 spring Chinook salmon at the LBC trap, (2) the BY02 fall Chinook salmon annual JPI (581,677) was lower than all previously reported brood years (BY98, BY99, and BY01) at the LBC trap, (3) the BY03 late-fall Chinook salmon annual JPI (31,538) was lower than all previously reported brood years (BY99, BY00, and BY02) at the LBC trap, (4) the BY02 spring Chinook salmon annual JPI at the UBC trap was higher than the BY01 annual JPI, but lower than BY98 and BY99, and (5) the BY02 fall Chinook salmon annual JPI at the UBC trap was lower than the BY98, BY99, and BY01 annual JPI's (Tables 12 and 13). Rainbow trout/steelhead annual JPI's at both traps were also significantly lower. During the current reporting period, the combined annual JPI for age 1+ and yoy trout at the LBC trout was 2,890, while the annual JPI's for all other years reported were >7,000. Similarly, the combined annual JPI for age 1+ and yoy trout at the UBC trap was 7,679, while during all other years reported, the annual JPI varied from 10,388 to 25,710. A variety of factors may be responsible for the reduced juvenile passage indices, including reduced adult passage, poor adult survival and spawning success, reduced survival to emergence, and inaccurate estimates of actual juvenile passage.

The annual JPI estimate for BY02 spring Chinook salmon at the LBC trap was lower than in 2001, but reasons for the difference are not readily apparent because of confounding factors. The overlap in the ranges of size that occurs when using the length-at-date criteria to assign a run designation may result in underestimates of spring Chinook salmon and overestimates of fall Chinook salmon. Although no estimates of adult spring Chinook salmon escapement were made below the barrier weir, it is possible that some spawned downstream, but there would be no way to distinguish spring chinook salmon produced above the barrier weir from those produced below the barrier weir. Ideally all adult spring Chinook salmon were passed upstream of the barrier weir, and passage of juvenile spring-run is likely better estimated using the UBC trap.

The decrease in BY02 fall Chinook salmon juvenile passage estimates at the LBC trap may be directly related to the extremely large number of fall Chinook salmon adults spawning below the barrier weir. Low juvenile passage estimates may also be due to low flows and high water temperatures during the fall and high scouring flows during the winter. In 2002, the estimated adult escapement of fall Chinook salmon below the weir was 463,296 of which 66,147 were taken into Coleman National Fish Hatchery (CNFH; CDFG 2007). The remaining 397,149 estimated to be downstream of the barrier weir was about four times higher than any previously recorded escapement (100,604 in 2001). In addition to a record high escapement, mean daily flows from mid-March to early November were similar to those observed in 2001 which were the lowest since we began monitoring juvenile passage on Battle Creek in 1998. Mean daily flows at the USGS gauging station located near the CNFH were <7.4 m^3/s (260 cfs) from July 1 to October 29, 2002 (Figure 17), which coincides with the migration and spawning periods for spring and fall Chinook salmon. Higher than average temperatures occurred during this time, but comparisons of mean daily temperatures in 2001 and 2002 cannot be made because no temperature data was collected at the screw traps from mid-February to early July 2001. However, mean daily temperatures from early April to mid-August were higher in 2002 than in 1998, 1999, and 2000 (Figure 18). Lack of available spawning habitat, low flows and high water temperatures in fall 2002 probably contributed to the high levels of pre-spawn mortality that occurred during spawning (87.5%; C. Harvey-Arrison, CDFG, personal communication). Redd superimposition likely also occurred, further impacting juvenile production.

High flow events in December and January may have also contributed to the decrease observed in juvenile spring and fall Chinook salmon passage estimates. From December 16, 2002 to January 13, 2003 there were four high flow events with peak flows >141.6 m^3/s (5,000 cfs); therefore, it is possible that scouring of spring and fall Chinook salmon redds occurred, and it is also possible that juvenile Chinook salmon were washed downstream during these events without being captured as the traps were not operated during these flow events.

The release of hatchery fall Chinook salmon in April and possibly late-May likely influenced the accuracy of our fall Chinook salmon weekly JPI's during that time. No hatchery fall Chinook salmon were marked in 2003; therefore we were not able to estimate the proportion of hatchery fish captured in the LBC trap. To prevent overestimating daily catch of larger fish in April, we did not include any fish >45 mm in our daily counts which likely resulted in an underestimation of our daily catch. In April these larger fish are primarily spring and fall Chinook salmon. In addition, in late-May large numbers of Chinook salmon 72-100 mm in length were captured in the LBC trap that appeared to be of hatchery origin because they exhibited fin erosion that is common in hatchery fish; therefore, during this time, all fish that exhibited fin erosion were not included in our daily counts. It is likely that we underestimated our daily catch of fall and spring Chinook salmon in April and either over or underestimated catch in late May. Excluding larger fish in April likely also affected our life-stage composition for these runs.

The annual JPI estimate for BY03 late-fall Chinook salmon was lower than all previous brood years, but reasons for the decrease are not readily apparent because of confounding factors. As seen with spring Chinook salmon, the length-at-date criteria used to assign run designation does not appear to be accurate because there was overlap in size range with fall Chinook salmon. In other words, Chinook salmon fry that were classified as fall-run in March through May were likely late-fall run. In addition, in-river adult escapement estimates below the barrier weir were not available for late-fall Chinook salmon; therefore, if a decrease in adult escapement occurred, it was not apparent. The only estimate of escapement available was the number taken into the hatchery. In 2003, 2,838 late-fall Chinook salmon were taken into the hatchery versus the 2,669 taken in to the hatchery in 2002 (CDFG 2007). Low flows and high temperatures were likely not a problem because the migration period for BY03 late-fall Chinook salmon is usually October through March, and spawning occurs from January through April when flows and water temperatures were suitable for holding, spawning, and incubation.

Rainbow trout/steelhead annual JPI estimates at the lower trap were significantly lower in 2002 than all previous estimates. However, no estimates of adult escapement or spawning success are available downstream of the barrier weir. Many of the juvenile rainbow trout/steelhead captured in the trap were likely migrants from upstream of the barrier weir; therefore, trout passage is probably better estimated using the UBC trap. Reasons for the decrease observed at the lower trap are likely similar to those for the UBC trap.

The UBC trap monitors juvenile production (passage) from adult spring, fall, and late-fall Chinook salmon and rainbow trout/steelhead escapement above the barrier weir. In 2002, the spring Chinook salmon annual JPI was higher than BY01 but lower than BY98 and BY99, and the fall Chinook salmon annual JPI was lower than all previous annual JPI's. However, the length-at-date criteria used to assign a run designation to Chinook salmon captured in the trap was developed for the Sacramento River and is not accurate when used in Battle Creek. For example, escapement estimates of adult Chinook salmon upstream of the weir based on weir counts, stream surveys, and genetic analyses were 144 spring-run, 42 fall-run, 33 late-fall run, and 3 winter-run (Brown et al. 2005). Juvenile passage estimates appear to indicate that spring Chinook salmon production was significantly lower than fall Chinook salmon, but it is more likely that many of the juvenile Chinook salmon classified as fall-run were actually spring-run. If combined, juvenile passage for spring and fall Chinook salmon was only slightly lower than seen in 2001, but substantially lower than 1998-2000.

Reduced adult escapement of spring and fall Chinook salmon does not appear to have been responsible for the decrease because estimated escapement of adult Chinook salmon above the weir was higher in 2002 (N=222) than in each year from 1998 through 2001 (Brown and Newton 2002; J. M. Newton, USFWS, RBFWO, unpublished data). Rather, warm water temperatures and low flows during the adult holding and spawning period may be responsible for the decreases in juvenile spring and fall Chinook salmon passage estimates. Pre-spawning mortality may have been a significant factor during the long summer holding period when water temperatures were high and fish were exposed to high temperatures. Fourteen of the 34 (41%) carcasses sampled in Battle Creek were observed prior to redd construction, and only 78 redds were counted during spawning surveys which is lower than would be expected for an adult escapement of 222 (Brown et al. 2005). Similar to 2001, minimum instream flows in South Fork Battle Creek were reduced in 2002, resulting in higher water temperatures during the Chinook salmon holding and spawning periods. On June 27, 2002 interim flows in the south fork were increased from 0.14 m^3/s (5 cfs) to 0.28 m^3/s (10 cfs), but the north fork interim flows were decreased by 0.14 m^3/s (5 cfs) at the same time (J. M. Newton, USFWS, RBFWO, personal communication). Interim flows in the south fork were not increased to 0.71 m^3/s (25 cfs) until October 21, 2002. In comparison, minimum instream flows of at least 0.85 m^3/s (30 cfs) were provided in both the North Fork Battle Creek and the South Fork Battle Creek in 1998 to 2000 (Figure 17). Similar to 2001, an above average proportion of Chinook salmon held and spawned in the south fork in 2002 (58% of adults and 21% of redds; Brown et al. 2005).

The BY03 late-fall Chinook salmon annual JPI at the UBC trap was not significantly different than the BY02. However, juvenile late-fall Chinook salmon production per number of spawners appears to have been higher in 2002 than 2001 because although a similar number of juveniles were produced fewer adults were passed upstream of the weir. During their late-fall Chinook propagation program, CNFH passes unclipped (i.e., natural) Chinook salmon upstream of the barrier weir generally from late December through February. Coleman National Fish Hatchery passed 216 unclipped Chinook during December 2001-February 2002 (Brown et al. 2005) but only 57 during December 2002-February 2003 (Brown and Alston 2007). It is possible that some of these fish were not late-fall, but run-timing suggests otherwise. The increased juvenile production per number of spawners may be the result of high adult survival and spawning success, and survival to emergence. The average mean daily flow for the period January to July was higher in 2003 than 2002 (Figure 17) which provided more suitable environmental conditions for adult and juvenile late-fall Chinook salmon in 2003.

The combined 2003 rainbow trout/steelhead annual JPI estimate of 7,679 for the UBC trap was significantly lower than all previous estimates (Table 13). A reduction in adult escapement and high flows may have contributed to the decrease. Between October 2002 and August 29, 2003 there were 1,318 clipped and unclipped rainbow trout/steelhead passed upstream of the barrier weir, while in 2001 to 2002 a total of 2,035 clipped and unclipped were passed upstream of the weir. In Battle Creek rainbow trout/steelhead fry typically begin migrating past the UBC trap in February and March, but in 2003 few fry were captured in the traps in comparison to 2000 and 2002 (Whitton et al. 2006, Whitton et al. 2007). Between January 11 and March 26, 2003 there were 7 d where stream flows at the USGS gauge station, located downstream of the UBC trap, exceeded 3,500 cfs. Two storms events in mid to late-March had maximum flows of 4,350 and 5,930 cfs. It is possible that either redds were scoured during these events or that juvenile trout were washed downstream without being captured. If redd scour due to high flows negatively impacted rainbow trout/steelhead production in 2003, this effect was not apparent in the late-fall Chinook salmon JPI although spawning occurs at a similar time.

> ***Recommendation:*** *Investigate the relationship between flows and redd scour and the impact on juvenile passage.*

Survival to emergence data is not available for any year; therefore it is not possible to determine whether the low flows and temperatures observed in 2002 influenced juvenile spring and fall Chinook salmon survival and the resulting passage estimates. However, Brown et al. (2005) stated there was likely some temperature related egg mortality. In addition, they found that some incubating eggs experienced high temperatures in the south fork, upper mainstem Battle Creek, and potentially the north fork. Limited exposure to high temperatures may account for some of the reduction in juvenile passage, but it may not be the primary cause. Estimates of survival to emergence would provide further information allowing us to better determine which factors may be affecting annual juvenile passage.

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Tables

Table 1. Life-stage summary of spring, fall, late-fall, and winter Chinook salmon and rainbow trout/steelhead captured at the Lower and Upper Battle Creek rotary screw traps from October 1, 2002 through September 30, 2003.

	Spring Chinook		Fall Chinook		Late-Fall Chinook		Winter Chinook		Rainbow	
Life Stage	#	%	#	%			#	%	#	%
					Lower Battle Creek (LBC)					
Yolk Sac Fry	---	---	---	---	---	---	---	---	1	0.5
Fry	10	5.6	12,308	79.8	1,905	91.9	6	7.7	26	12.1
Parr	42	23.4	1,490	9.7	142	6.8	26	33.3	151	70.6
Silvery Parr	80	44.7	1,518	9.8	16	0.8	40	51.3	22	10.3
Smolt	47	26.3	113	0.7	11	0.5	6	7.7	14	6.5
Totals	179	100	15,429	100	2,074[a]	100	78	100	214	100
					Upper Battle Creek (UBC)					
Yolk Sac Fry	---	---	---	---	---	---	---	---	2	0.8
Fry	4	12.9	595	86.7	209	100	1	50.0	63	24.5
Parr	3	9.7	13	1.9	---	---	---	---	169	65.8
Silvery Parr	8	25.8	62	9.0	---	---	---	---	18	7.0
Smolt	16	51.6	16	2.3	---	---	1	50.0	5	1.9
Totals	31	100	686	100	209[b]	100	2	100	257	100

[a] An additional 28 late-fall Chinook salmon were sampled at the LBC trap from 10/1/03 to 12/31/03, including 16 silvery parr and 12 smolt.
[b] One additional late-fall Chinook salmon smolt was sampled at the UBC trap from 10/1/03 to 12/31/03.

Table 2. Summary of the mark-recapture trials conducted at the Lower Battle Creek rotary screw trap (LBC) from October 1, 2002 through September 30, 2003. Marked fish for all LBC trials were released at the Jelly's Ferry Bridge. Shaded rows indicate weeks where mark-recapture data were pooled for analysis. Trials conducted during the same week were pooled to calculate the average weekly trap efficiency. During weeks when recaptures were <7 mark-recapture data from adjacent weeks were pooled if flows and trap efficiencies were similar, otherwise the season average trap efficiency (*E=0.132*) was used to calculate weekly passage. The season average trap efficiency was also used to calculate passage during weeks when no mark-recapture trials were conducted. Trials highlighted with **bold text** were not used.

Release Date	Time of Release	Number Released	Recaptures	Efficiency[a]	Pooled /Season Avg. Efficiency	Weekly Mean Flow, m^3/s (cfs)
01/22/03 [b]	**1842**	**202**	**0**	**---**	***0.132***	**28.4 (1,004)**
01/28/03	1755	454	35	0.079	0.081	20.6 (728)
01/31/03	2135	214	18	0.088	0.081	20.6 (728)
02/03/03	1830	139	6	0.050	0.114	15.4 (545)
02/06/03	1905	289	42	0.148	0.114	15.4 (545)
02/10/03	1800	284	47	0.168	0.106	19.7 (697)
02/13/03	1804	516	37	0.074	0.106	19.7 (697)
02/17/03	1845	250	15	0.064	0.090	16.8 (595)
02/20/03	1800	481	50	0.106	0.090	16.8 (595)
02/27/03	1845	495	119	0.242	---	12.8 (453)
03/03/03	1915	245	36	0.150	0.165	11.2 (394)
03/06/03	1830	482	83	0.174	0.165	11.2 (394)
03/10/03	1930	328	75	0.231	0.187	24.5 (864)
03/13/03	1850	328	47	0.146	0.187	24.5 (864)
03/20/03	1900	132	10	0.083	---	17.8 (630)
03/26/03	**2104**	**73**	**2**	**0.041**	***0.132***	**27.7 (979)**
05/06/03	2001	246	17	0.073	0.073	26.6 (939)
05/20/03	**2032**	**143**	**5**	**0.042**	***0.132***	**23.4 (828)**

[a] Bailey's Efficiency was calculated by: $\hat{E} = \frac{r+1}{m+1}$, where r = recaptures and m = number of marked fish released.

[b] Due to high flows, the LBC trap was pulled on 01/22/03 after the release.

Table 3. Summary of the mark-recapture trials conducted at the Upper Battle Creek rotary screw trap (UBC) during October 10, 2002 through September 30, 2003. Marked fish for all UBC trials were released at Intake 3. Shaded rows indicate weeks where mark-recapture data were pooled for analysis. Trials conducted during the same week were pooled to calculate the average weekly trap efficiency. During weeks when recaptures were <7, mark-recapture data from adjacent weeks were pooled if flows and trap efficiencies were similar, otherwise the season average trap efficiency (*E=0.054*) was used to calculate weekly passage. The season average trap efficiency was also used to calculate passage during weeks when no mark-recapture trials were conducted. Trials highlighted with **bold text** were not used.

Release Date	Release Time	Number Released	Recaptures	Efficiency[a]	Pooled /Season Avg. Efficiency	Weekly Mean Flow, m^3/s (cfs)
01/22/03[b]	**1735**	**168**	**0**	---	*0.054*	28.4 (1,004)
01/28/03	1809	400	33	0.085	0.078	20.6 (728)
01/31/03	2200	212	14	0.070	0.078	20.6 (728)
02/03/03[c]	**1900**	**125**	**0**	---	---	15.4 (545)
02/06/03	1920	292	23	0.082	0.082	15.4 (545)
02/10/03	1818	289	20	0.072	0.044	19.7 (697)
02/13/03	1823	491	13	0.028	0.044	19.7 (697)
02/17/03	1900	238	2	0.013	0.031	16.8 (595)
02/20/03	1820	498	20	0.042	0.031	16.8 (595)
02/27/03	1910	492	37	0.076	---	12.8 (453)
03/03/03	1940	240	13	0.058	0.058	11.2 (394)
03/06/03	1839	477	28	0.061	0.058	11.2 (394)
03/10/03	1945	332	14	0.045	0.046	24.5 (864)
03/13/03	1900	327	15	0.049	0.046	24.5 (864)
03/20/03	**1913**	**131**	**6**	0.053	*0.054*	17.8(630)
03/26/03	**2117**	**70**	**1**	0.028	*0.054*	27.7 (979)
04/02/03	1847	99	4	0.050	0.048	20.6 (726)
04/09/03	1611	86	4	0.057	0.048	20.3 (717)
04/16/03	1958	266	10	0.041	---	19.5 (689)
04/23/03	2012	258	8	0.035	---	25.8 (910)

[a] Bailey's Efficiency is calculated by: $\hat{E} = \dfrac{r+1}{m+1}$, where r = recaptures and m = marks.

[b] Due to high flows, the UBC trap was pulled on 01/22/03 after the release.

[c] This mark-recapture trial was not used because a stick in the trap prevented it from rotating.

Table 4. Weekly summary of brood year 2002 juvenile spring Chinook salmon passage estimates for the Lower Battle Creek rotary screw trap, including week, efficiency (E), catch, estimated passage (N), standard error (SE), and the 90 and 95% confidence intervals (CI). Only weeks in which spring Chinook salmon were captured are included.

Week	Efficiency (E)	Catch[b]	Estimated Passage (N)	SE[c]	90% Confidence Interval[c] Lower CI	90% Confidence Interval[c] Upper CI	95% Confidence Interval[c] Lower CI	95% Confidence Interval[c] Upper CI
12/16/02	0.132[a]	1	8	0.9	6.3	9.5	6.1	9.1
12/23/02	0.132[a]	17	129	14.2	108	152	104	162
12/30/02	0.132[a]	2	15	1.8	13	18	12	19
01/06/03	0.132[a]	2	15	1.6	13	18	12	19
01/13/03	0.132[a]	1	8	0.9	6.4	9.2	6.1	9.5
02/03/03	0.114	1	9	1.3	7.0	11.3	6.7	11.9
02/10/03	0.106	1	9	1.0	8.0	11.2	7.7	11.6
02/17/03	0.090	1	11	1.3	9.2	13.3	8.8	13.8
02/24/03	0.242	11	45	3.6	40	52	39	53
03/03/03	0.165	32	194	16.4	170	224	165	228
03/10/03	0.187	6	32	2.6	28	37	27	38
03/17/03	0.083	38	459	142.9	297	722	281	842
03/24/03	0.132[a]	100	758	85.2	640	907	611	971
03/31/03	0.132[a]	32	242	26.5	202	290	198	300
04/07/03	0.132[a]	2	15	1.7	13	18	12	19
05/05/03	0.073	4	55	12.6	37	76	35	82
05/12/03	0.132[a]	20	152	16.9	127	181	122	188
05/19/03	0.132[a]	18	136	15.2	114	163	110	169
05/26/03	0.132[a]	2	15	1.6	13	18	12	19
06/02/03	0.132[a]	1	8	0.8	6.3	9.1	6.1	9.4
Totals	**---**	***292***	***2,315***	***176.6***	***2,078***	***2,628***	***2,037***	***2,713***

[a] The 2002 to 2003 season average efficiency, which was based on valid trials conducted January 22, 2003 through May 20, 2003, was used to estimate passage during weeks when mark-recapture trials were not conducted.
[b] Daily catch was estimated for days the trap was not fishing.
[c] Confidence intervals were calculated using the percentile bootstrap method and SE's were calculated using bootstrapped values.

Table 5. Weekly summary of brood year 2002 juvenile fall Chinook salmon passage estimates for the Lower Battle Creek rotary screw trap, including week, efficiency (E), catch, estimated passage (N), standard error (SE), and the 90 and 95% confidence intervals (CI).

Week	Efficiency (E)	Catch[b]	Estimated Passage (N)	SE[c]	90% Confidence Interval[c]		95% Confidence Interval[c]	
					Lower CI	Upper CI	Lower CI	Upper CI
12/09/02	0.132[a]	51	386	44	323	462	308	478
12/16/02	0.132[a]	52	394	45	329	471	318	488
12/23/02	0.132[a]	292	2,212	244	1,847	2,604	1,785	2,739
12/30/02	0.132[a]	209	1,583	183	1,322	1,895	1,292	1,995
01/06/03	0.132[a]	816	6,182	693	5,102	7,398	4,988	7,654
01/13/03	0.132[a]	828	6,273	701	5,238	7,507	5,119	7,766
01/20/03	0.132[a]	3,194	24,197	2,730	20,442	28,959	19,745	30,483
01/27/03	0.081	8,144	100,895	13,381	81,318	123,826	77,833	129,722
02/03/03	0.114	5,539	48,495	6,475	38,326	59,406	37,718	62,532
02/10/03	0.106	13,991	131,845	13,786	112,068	157,842	107,758	162,417
02/17/03	0.090	10,572	117,253	14,290	96,734	140,704	93,237	148,821
02/24/03	0.242	9,500	39,267	3,114	34,647	44,876	33,657	46,196
03/03/03	0.165	7,205	43,710	3,572	38,286	49,955	37,466	509,925
03/10/03	0.187	1,679	8,968	754	7,879	10,309	7,660	10,710
03/17/03	0.083	1,201	14,521	4,397	8,874	22,819	8,407	26,622
03/24/03	0.132[a]	1,028	7,788	869	6,503	9,321	6,355	9,811
03/31/03	0.132[a]	527	3,992	450	3,334	4,859	3,221	4,943
04/07/03	0.132[a]	347	2,629	301	2,195	3,199	2,097	3,255
04/14/03	0.132[a]	53	402	46	331	481	324	497
04/21/03	0.132[a]	30	227	26	185	272	179	281
04/28/03	0.132[a]	27	205	23	171	245	165	253
05/05/03	0.073	39	535	132	371	803	357	876
05/12/03	0.132[a]	193	1,462	163	1,221	1,750	1,193	1,842
05/19/03	0.132[a]	735	5,568	639	4,649	6,777	4,493	7,015
05/26/03	0.132[a]	615	4,659	515	3,890	5,576	3,802	5,768
06/02/03	0.132[a]	577	4,371	472	3,650	5,231	3,527	5,412
06/09/03	0.132[a]	260	1,970	226	1,645	2,397	1,607	2,481
06/16/03	0.132[a]	126	955	105	797	1,142	770	1,182
06/23/03	0.132[a]	71	538	61	444	644	434	678
06/30/03	0.132[a]	19	144	16	120	172	116	178
07/07/03	0.132[a]	6	45	5	38	54	37	55

Table 5. (Cont.)

07/14/03	0.132[a]	5	38	4	32	45	31	47
07/21/03	0.132[a]	1	8	1	6.3	9.1	6.2	9.4
Totals	---	***67,932***	***581,677***	***25,574***	***542,513***	***625,834***	***537,926***	***636,193***

[a] Season average efficiency based on valid trials conducted January 22, 2003 through May 20,2003.
[b] Daily catch was estimated for days the trap was not fishing.
[c] Confidence intervals were calculated using the percentile bootstrap method and SE's were calculated using bootstrapped values.

Table 6. Weekly summary of brood year 2003 juvenile late-fall Chinook salmon passage estimates for the Lower Battle Creek rotary screw trap, including week, efficiency (E), catch, estimated passage (N), standard error (SE), and the 90 and 95% confidence intervals (CI). Only weeks in which late-fall Chinook salmon were captured are included. However, several weeks outside of the reporting dates (October 1 to December 24, 2003) are included to allow estimation of the total annual JPI for brood year 2003 (below dashed line).

Week	Efficiency (E)	Catch[b]	Estimated Passage (N)	SE[c]	90% Confidence Interval[c] Lower CI	90% Confidence Interval[c] Upper CI	95% Confidence Interval[c] Lower CI	95% Confidence Interval[c] Upper CI
03/24/03	0.132[a]	14	106	12	90	127	87	131
03/31/03	0.132[a]	76	576	65	481	689	465	725
04/07/03	0.132[a]	92	697	78	582	834	569	878
04/14/03	0.132[a]	201	1,523	174	1,286	1,853	1,243	1,953
04/21/03	0.132[a]	629	4,765	537	3,979	5,703	3,845	5,900
04/28/03	0.132[a]	666	5,045	560	4,262	6,141	4,117	6,356
05/05/03	0.073	310	4,254	948	2,945	5,890	2,836	6,381
05/12/03	0.132[a]	229	1,735	191	1,449	2,042	1,400	2,111
05/19/03	0.132[a]	528	4,000	455	3,302	4,787	3,227	5,039
05/26/03	0.132[a]	451	3,417	374	2,820	4,022	2,757	4,230
06/02/03	0.132[a]	331	2,508	275	2,094	3,001	2,046	3,105
06/09/03	0.132[a]	197	1,492	168	1,246	1,816	1,207	1,848
06/16/03	0.132[a]	59	447	48	378	535	365	553
06/23/03	0.132[a]	50	379	45	316	461	309	477
06/30/03	0.132[a]	13	98	11	81	118	79	122
07/07/03	0.132[a]	6	45	5	38	54	37	55
07/14/03	0.132[a]	4	30	3	25	36	24	38
07/21/03	0.132[a]	1	8	0.8	6.3	9.1	6.2	9.4
10/1 to 12/31/03	0.063	26	413	74	313	558	299	584
Totals	***---***	***3,883***	***31,538***	***1,425***	***29,371***	***34,089***	***29,126***	***34,580***

[a] The 2002 to 2003 season average efficiency, which was based on valid trials conducted January 22, 2003 through May 20, 2003, was used to estimate passage during weeks when mark-recapture trials were not conducted.
[b] Daily catch was estimated for days the trap was not fishing.
[c] Confidence intervals were calculated using the percentile bootstrap method and SE's were calculated using bootstrapped values.
[d] The 2003 to 2004 season average trap efficiency was used to estimate passage for weeks outside of the reporting period.

Table 7. Weekly summary of rainbow trout/steelhead passage estimates for the Lower Battle Creek rotary screw trap, including week, efficiency (E), catch, estimated passage (N), standard error (SE), and the 90 and 95% confidence intervals (CI). Weekly estimates listed above the dotted line are for trout from previous brood years (age 1+). Weekly estimates below the line are for brood year 2003 trout captured during the reporting period. Weeks with no catch are not included.

Week	Efficiency (E)	Catch[b]	Estimated Passage (N)	SE[c]	90% Confidence Interval[c]		95% Confidence Interval[c]	
					Lower CI	Upper CI	Lower CI	Upper CI
Previous Brood Years (Age 1+)								
10/07/02	0.132[a]	3	23	2.6	19	27	18	29
10/14/02	0.132[a]	10	76	8.7	63	92	60	97
10/21/02	0.132[a]	3	23	2.5	19	27	18	29
12/09/02	0.132[a]	4	30	3.5	25	37	24	39
12/16/02	0.132[a]	21	159	18.3	133	190	130	200
12/23/02	0.132[a]	1	8	0.9	6.3	9.1	6.1	9.5
12/30/02	0.132[a]	5	38	4.2	32	45	31	48
01/13/03	0.132[a]	2	15	1.7	13	18	12	19
01/27/03	0.087	1	12	1.7	10	15	9.6	16
02/10/03	0.106	3	28	2.9	24	33	23	35
03/03/03	0.165	1	6	0.5	5.3	7.0	5.2	7.2
04/28/03	0.132[a]	2	15	1.7	13	18	12	19
05/12/03	0.132[a]	8	61	6.6	51	73	50	75
05/19/03	0.132[a]	2	15	1.7	13	18	12	19
05/26/03	0.132[a]	2	15	1.6	13	18	12	19
06/02/03	0.132[a]	5	38	4.2	32	46	31	47
06/09/03	0.132[a]	2	15	1.7	13	18	12	19
Totals	---	***75***	***577***	***25.7***	***540***	***622***	***533***	***632***
Brood Year 2003 (YOY)								
02/10/03	0.106	2	19	1.9	16	22	15	23
03/03/03	0.165	2	12	1.0	10.6	13.9	10.3	14.4
03/10/03	0.187	3	16	1.3	14.1	18.3	13.7	18.6
03/24/03	0.132[a]	13	98	10.7	82	116	79	122
03/31/03	0.132[a]	3	23	2.5	19	27	18	28
04/07/03	0.132[a]	2	15	1.7	13	18	12	19
04/14/03	0.132[a]	3	23	2.6	19	27	18	29
04/21/03	0.132[a]	14	106	12.3	88	127	86	134

Table 7. (Contin.)

04/28/03	0.132[a]	22	167	19.3	138	203	133	210
05/05/03	0.073	20	274	65.1	190	380	176	449
05/12/03	0.132[a]	23	174	18.9	145	209	142	216
05/19/03	0.132[a]	47	356	39.4	301	426	291	449
05/26/03	0.132[a]	33	250	26.6	209	294	204	310
06/02/03	0.132[a]	30	227	24.9	190	268	185	281
06/09/03	0.132[a]	20	152	16.4	127	178	127	188
06/16/03	0.132[a]	24	182	21.3	150	218	143	225
06/23/03	0.132[a]	14	106	11.6	90	125	87	131
06/03/03	0.132[a]	6	45	5.4	38	55	37	57
07/07/03	0.132[a]	2	15	1.7	13	18	12	19
07/14/03	0.132[a]	6	45	4.9	38	54	37	55
07/21/03	0.132[a]	1	8	0.8	6.3	9.1	6.2	9.4
Totals		***290***	***2,313***	***97.6***	***2,164***	***2,479***	***2,187***	***2,520***

[a] Season average efficiency based on valid trials conducted January 22, 2003 through May 20, 2003.
[b] Daily catch was estimated for days the trap was not fishing.
[c] Confidence intervals were calculated using the percentile bootstrap method and SE's were calculated using bootstrapped values.

Table 8. Weekly summary of brood year 2002 juvenile spring Chinook salmon passage estimates for the Upper Battle Creek rotary screw trap, including week, efficiency (E), catch, estimated passage (N), standard error (SE), and the 90 and 95% confidence intervals (CI). Only weeks in which spring Chinook salmon were captured are included.

Week	Efficiency (E)	Catch[b]	Estimated Passage (N)	SE[c]	90% Confidence Interval[c]		95% Confidence Interval[c]	
					Lower CI	Upper CI	Lower CI	Upper CI
12/09/02	0.054[a]	1	19	4	14	26	13	28
12/23/02	0.054[a]	1	19	4	14	26	13	28
02/03/03	0.057	1	12	2	9	17	8	18
02/24/03	0.076	1	13	2	10	17	10	18
03/10/03	0.046	2	43	8	33	59	32	62
03/17/03	0.054[a]	4	74	15	54	100	51	105
03/24/03	0.054[a]	3	56	11	42	75	40	79
03/31/03	0.048	2	41	14	25	64	23	74
04/14/03	0.041	4	97	36	59	153	56	178
04/21/03	0.035	6	173	74	104	259	97	311
04/28/03	0.054[a]	6	111	22	81	150	79	158
05/05/03	0.054[a]	5	93	18	68	125	66	139
05/12/03	0.054[a]	7	130	27	97	175	90	195
05/19/03	0.054[a]	2	37	7	27	50	26	56
05/26/03	0.054[a]	2	37	8	28	50	26	56
Totals	**---**	***47***	***955***	***96***	***833***	***1,114***	***819***	***1,152***

[a] Season average efficiency based on valid trials conducted January 22 through April 23, 2003.
[b] Daily catch was estimated for days the trap was not fishing.
[c] Confidence intervals were calculated using the percentile bootstrap method and SE's were calculated using bootstrapped values.

Table 9. Weekly summary of brood year 2002 juvenile fall Chinook salmon passage estimates for the Upper Battle Creek rotary screw trap, including week, efficiency (E), catch, estimated passage (N), standard error (SE), and the 90 and 95% confidence intervals (CI). Shaded rows indicate adjacent weeks where the results of mark-recapture trials were pooled to calculate passage.

Week	Efficiency (E)	Catch[b]	Estimated Passage (N)	SE[c]	90% Confidence Interval[c] Lower CI	90% Confidence Interval[c] Upper CI	95% Confidence Interval[c] Lower CI	95% Confidence Interval[c] Upper CI
12/02/02	0.054[a]	1	19	4	14	27	13	28
12/09/02	0.054[a]	3	56	11	42	75	40	84
12/16/02	0.054[a]	17	315	64	230	448	218	473
12/23/01	0.054[a]	47	872	164	654	1,177	620	1,308
12/30/02	0.054[a]	108	2,004	389	1,461	2,705	1,424	2,848
01/06/03	0.054[a]	101	1,874	359	1,368	2,530	1,332	2,811
01/13/03	0.054[a]	284	5,270	968	3,846	6,775	3,744	7,489
01/20/03	0.054[a]	130	2,412	470	1,760	3,256	1,714	3,618
01/27/03	0.078	57	728	101	582	896	555	944
02/03/03	0.057	20	244	49	178	326	167	345
02/10/03	0.044	4	92	16	71	120	66	130
02/17/03	0.031	2	64	15	46	87	45	98
02/24/03	0.076	2	26	4	20	33	19	36
03/03/03	0.058	4	68	10	53	90	51	93
03/10/03	0.046	5	108	21	81	148	77	155
03/17/03	0.054[a]	7	130	26	95	175	90	185
03/24/03	0.054[a]	48	891	171	650	1,202	633	1,336
03/31/03	0.048	12	248	89	149	372	140	446
04/07/03	0.048	3	62	23	37	93	35	112
04/14/03	0.041	1	24	11	16	38	14	45
04/21/03	0.035	2	58	22	35	86	32	104
04/28/03	0.054[a]	3	56	11	41	75	39	84
05/05/03	0.054[a]	3	56	11	42	75	40	79
05/12/03	0.054[a]	12	223	39	167	286	158	301
05/19/03	0.054[a]	38	705	135	529	952	501	1,002
05/26/03	0.054[a]	24	455	87	325	601	308	633
06/02/03	0.054[a]	31	575	112	431	777	398	863
06/09 to 6/23/03	0.054[a]	8	148	29	111	200	105	210
Totals	---	***977***	***17,783***	***1,203***	***15,899***	***19,779***	***15,661***	***20,247***

[a] Season average efficiency based on valid trials conducted January 22, 2003 through April 23, 2003.
[b] Daily catch was estimated for days the trap was not fishing.
[c] Confidence intervals were calculated using the percentile bootstrap method and SE's were calculated using bootstrapped values.

Table 10. Weekly summary of brood year 2003 juvenile late-fall Chinook salmon passage estimates for the Upper Battle Creek rotary screw trap, including week, efficiency (E), catch, estimated passage (N), standard error (SE), and the 90 and 95% confidence intervals (CI). Only weeks which late-fall Chinook salmon were captured are included. A 3-month period outside of the reporting dates (October 1 to December 31, 2003) was included to allow estimation of the total annual JPI for brood year 2003 (below dashed line).

Week	Efficiency (E)	Catch[b]	Estimated Passage (N)	SE[c]	90% Confidence Interval[c]		95% Confidence Interval[c]	
					Lower CI	Upper CI	Lower CI	Upper CI
04/14/03	0.041	4	97	36	59	153	56	178
04/21/03	0.035	7	201	69	113	302	107	363
04/28/03	0.054[a]	19	353	65	264	476	251	501
05/05/03	0.054[a]	64	1,188	237	867	1,603	822	1,688
05/12/03	0.054[a]	32	594	114	445	802	422	844
05/19/03	0.054[a]	7	130	27	97	175	90	195
05/26/03	0.054[a]	1	19	4	14	25	13	28
06/02/03	0.054[a]	44	816	155	596	1,102	580	1,160
06/09/03	0.054[a]	102	1,893	349	1,420	2,555	1,345	2,690
06/16/03	0.054[a]	36	668	131	487	902	475	950
06/23/03	0.054[a]	27	501	98	366	676	347	712
06/30/03	0.054[a]	7	130	25	97	175	92	195
07/14/03	0.054[a]	1	19	4	14	25	13	28
10/1 to 12/31/03	0.078[d]	5	64	11	49	82	47	88
Totals	---	***357***	***6,702***	***496***	***5,865***	***7,442***	***5,734***	***7,677***

[a] Season average efficiency based on valid trials conducted January 22 through April 23, 2003.
[b] Daily catch was estimated for days the trap was not fishing.
[c] Confidence intervals were calculated using the percentile bootstrap method and SE's were calculated using bootstrapped values.
[d] Season average efficiency based on valid trials conducted January 14 through April 16, 2004.

Table 11. Weekly summary of rainbow trout/steelhead passage estimates for the Upper Battle Creek rotary screw trap, including week, efficiency (E), catch, estimated passage (N), standard error (SE), and the 90 and 95% confidence intervals (CI). Weekly estimates listed above the dotted line are for trout from previous brood years (age 1+). Weekly estimates below the line are for brood year 2003 trout captured during the reporting period. Shaded rows indicate adjacent weeks where the results of mark-recapture trials were pooled to calculate passage. Weeks with no catch are not included.

Week	Efficiency (E)	Catch[b]	Estimated Passage (N)	SE[c]	90% Confidence Interval[c] Lower CI	90% Confidence Interval[c] Upper CI	95% Confidence Interval[c] Lower CI	95% Confidence Interval[c] Upper CI
Previous Brood Years (Age 1+)								
11/04/02	0.054[a]	4	74	14	56	100	53	111
11/11/02	0.054[a]	5	93	18	68	125	64	132
12/16/02	0.054[a]	4	74	15	54	100	53	105
12/23/02	0.054[a]	1	19	4	14	26	13	28
01/06/03	0.054[a]	1	19	4	14	26	13	28
01/13/03	0.054[a]	1	19	4	14	26	13	28
01/20/03	0.054[a]	2	37	7	27	50	26	56
02/10/03	0.044	1	23	4	18	30	17	33
03/24/03	0.054[a]	1	19	4	14	26	13	28
03/31/03	0.048	5	103	36	62	155	58	186
05/12/03	0.054[a]	3	56	11	41	75	40	79
05/19/03	0.054[a]	1	19	4	14	25	13	26
05/26/03	0.054[a]	2	37	8	28	50	26	56
Totals	---	***31***	***592***	***48***	***522***	***671***	***511***	***698***
Brood Year 2003 (YOY)								
03/03/03	0.058	7	120	18	95	152	90	162
03/10/03	0.046	15	325	62	244	443	227	464
03/17/03	0.054[a]	2	37	7	27	50	26	56
03/24/03	0.054[a]	16	297	61	217	422	206	445
03/31/03	0.048	12	248	91	149	372	140	446
04/07/03	0.048	15	310	110	186	465	174	558
04/14/03	0.041	12	291	97	178	458	169	534
04/21/03	0.035	15	432	162	259	648	243	777
04/28/03	0.054[a]	28	520	100	379	701	369	779
05/05/03	0.054[a]	38	705	130	515	907	501	1,002
05/12/03	0.054[a]	33	612	119	447	827	435	919
05/19/03	0.054[a]	48	891	177	649	1,202	617	1,336

Table 11 (Cont.)

05/26/03	0.054[a]	33	612	117	459	827	435	870
06/02/03	0.054[a]	43	798	156	598	1,077	567	1,197
06/09/03	0.054[a]	26	482	88	302	651	343	686
06/16/03	0.054[a]	16	297	58	223	422	211	445
06/23/03	0.054[a]	7	130	26	95	175	90	185
06/30/03	0.054[a]	1	19	4	14	25	13	26
07/07/03	0.054[a]	1	19	4	14	25	13	26
Totals	**---**	***368***	***7,145***	***425***	***6,483***	***7,839***	***6,383***	***8,059***

[a] Season average efficiency based on valid trials conducted January 22 through April 23, 2003.
[b] Daily catch was estimated for days the trap was not fishing.
[c] Confidence intervals were calculated using the percentile bootstrap method and SE's were calculated using bootstrapped values.

Table 12. Summary of spring, fall, and late-fall Chinook salmon and rainbow trout/steelhead juvenile passage estimates at the Lower Battle Creek rotary screw trap including run designation, brood year, original CAMP estimate, current estimate (N), and the 90 and/or 95% confidence intervals for the current estimates. Shaded rows indicated estimates for the current reporting period.

Run	Brood Year	Original CAMP Estimate[c]	Current Estimate	90% Confidence Interval Lower CI	90% Confidence Interval Upper CI	95% Confidence Interval Lower CI	95% Confidence Interval Upper CI
Spring	1998	---	---	---	---	---	---
	1999	---	---	---	---	---	---
	2000	---	---	---	---	---	---
	2001		8,978	8,113	10,002	8,003	10,160
	2002		2,315	2,078	2,628	2,037	2,713
Fall	1998	4,909,700	4,897,569	---	---	4,238,511	5,732,692
	1999	16,697,610	18,708,768	---	---	14,103,348	26,372,818
	2000-partial[a]	---	5,451,599	---	---	4,270,908	7,182,598
	2001	---	4,040,686	3,721,942	4,413,372	3,676,854	4,522,353
	2002		581,677	542,513	625,834	537,926	636,193
Late-Fall	1999	113,684	86,305	---	---	72,258	98,591
	2000	99,803	86,940	---	---	73,793	106,967
	2001	---	---	---	---	---	---
	2002	---	59,183	50,087	72,672	48,738	75,194
	2003	---	31,538	29,371	34,371	29,126	34,580
RBT/Steelhead	1999[b]	---	7,057	---	---	6,196	8,368
	2000[b]	---	8,417	---	---	7,699	9,608
	2001	---	---	---	---	---	---
	2002 (1+)[d]	---	647	583	725	574	735
	2002 (YOY)	---	8,153	7,261	9,255	7,096	9,576
	2003 (1+)[d]		577	540	622	633	632
	2003 (YOY)		2,313	2,164	2,479	2,187	2,520

[a] This passage estimate is not a complete brood year as the trap was not fished past February 9, 2001.

[b] These estimates are not brood years, rather two periods are summarized: October 9, 1998 to December 26, 1999 and December 27, 1999 to February 9, 2001.

[c] The original CAMP estimates cover the period January 1 through December 31; therefore, they may not include the entire brood year, and late-fall estimates may include fish from two brood years.

[d] Passage estimates for age 1+ trout are not for the current brood year, but rather a mixture of previous year-classes captured during the reporting period.

Table 13. Summary of fall, late-fall, and spring Chinook salmon and rainbow trout/steelhead juvenile passage estimates at the Upper Battle Creek rotary screw traps including run designation, brood year, original CAMP estimate, current estimate (N), and the 90 and/or 95% confidence intervals for the current estimates. Shaded rows indicated estimates for the current reporting period.

		Original CAMP		90% Confidence Interval		95% Confidence Interval	
Run	Brood Year	Estimate[c]	Current Estimate	Lower CI	Upper CI	Lower CI	Upper CI
Spring	1998	4,589	4,791	---	---	3,949	6,204
	1999	10,061	6,233	---	---	5,225	7,678
	2000	---	---	---	---	---	---
	2001	---	482	389	615	377	644
	2002	---	926	810	1,070	798	1,102
Fall	1998	1,466,274	1,193,916	---	---	996,588	1,546,430
	1999	211,662	239,152	---	---	202,274	291,194
	2000-partial[a]	---	43,850	---	---	37,476	54,567
	2001	---	20,920	18,642	24,337	18,195	25,143
	2002	---	17,754	15,883	19,731	15,648	20,244
Late-Fall	1999	---	212	177	261	170	273
	2000	---	50	36	70	35	78
	2001	---	---	---	---	---	---
	2002	---	7,628	5,950	9,969	5,753	10,604
	2003	---	6,673	5,835	7,409	5,679	7,631
RBT/Steelhead	1999[b]	---	10,388	---	---	8,810	12,976
	2000[b]	---	25,710	---	---	21,865	30,713
	2001	---	---	---	---	---	---
	2002 (1+)[d]	---	1,348	1,201	1,607	1,170	1,666
	2002 (YOY)	---	24,740	21,034	29,565	20,454	31,426
	2003 (1+)[d]	---	592	522	671	511	698
	2003 (YOY)	---	7,087	6,441	7,769	6,349	7,978

[a] This passage estimate is not a complete brood year as the trap was not fished past February 9, 2001.
[b] These estimates are not brood years, rather two periods are summarized: October 9, 1998 to December 26, 1999 and December 27, 1999 to February 9, 2001.
[c] The original CAMP estimates cover the period January 1 through December 31; therefore, they may not include the entire brood year, and late-fall estimates may include fish from two brood years.
[d] Passage estimates for age 1+ fish are not for the current brood year, but rather a mixture of previous year-classes captured during the reporting period.

Figures

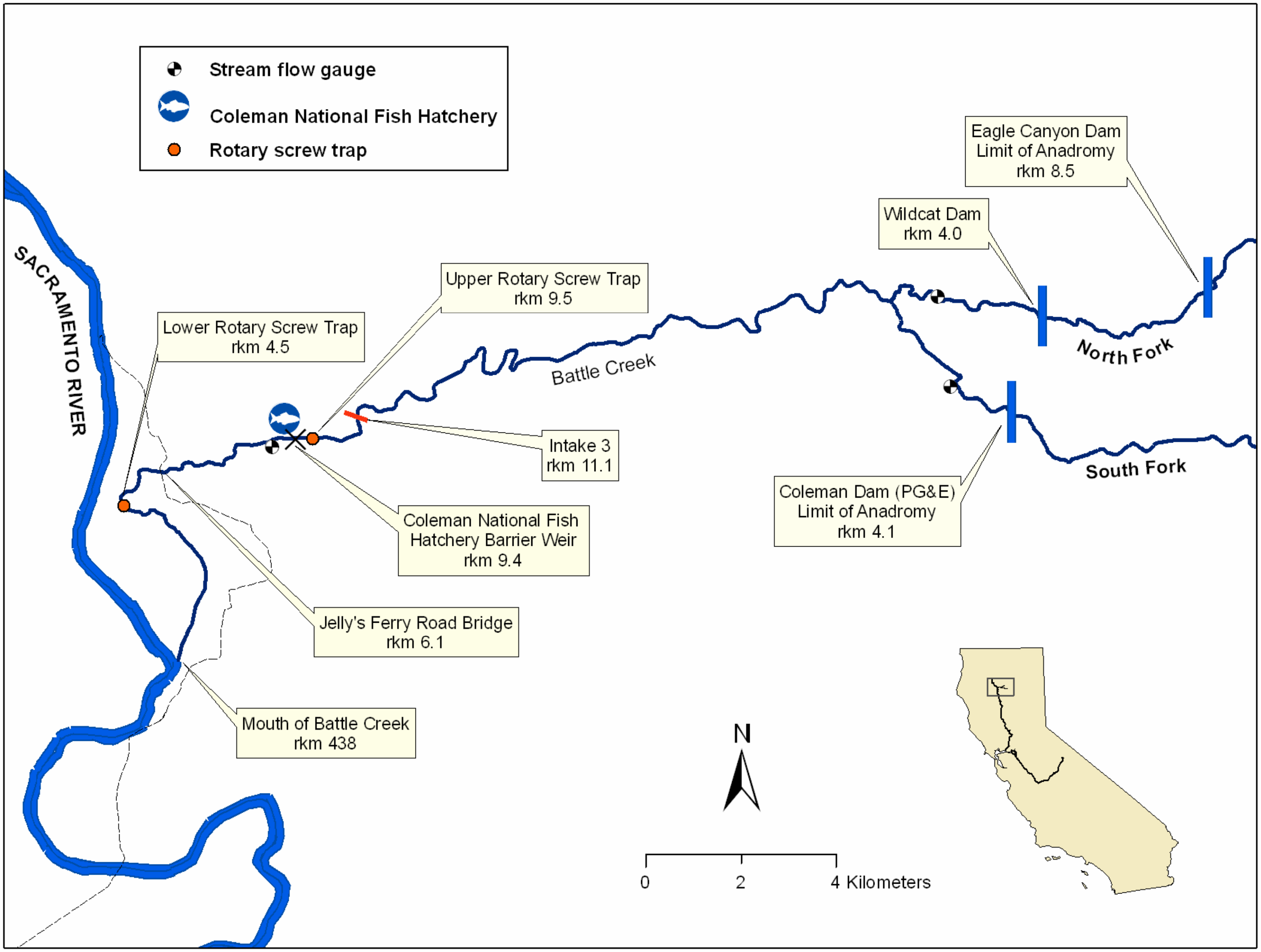

Figure 1. Map of Battle Creek depicting the location of USFWS' rotary screw traps and other important features.

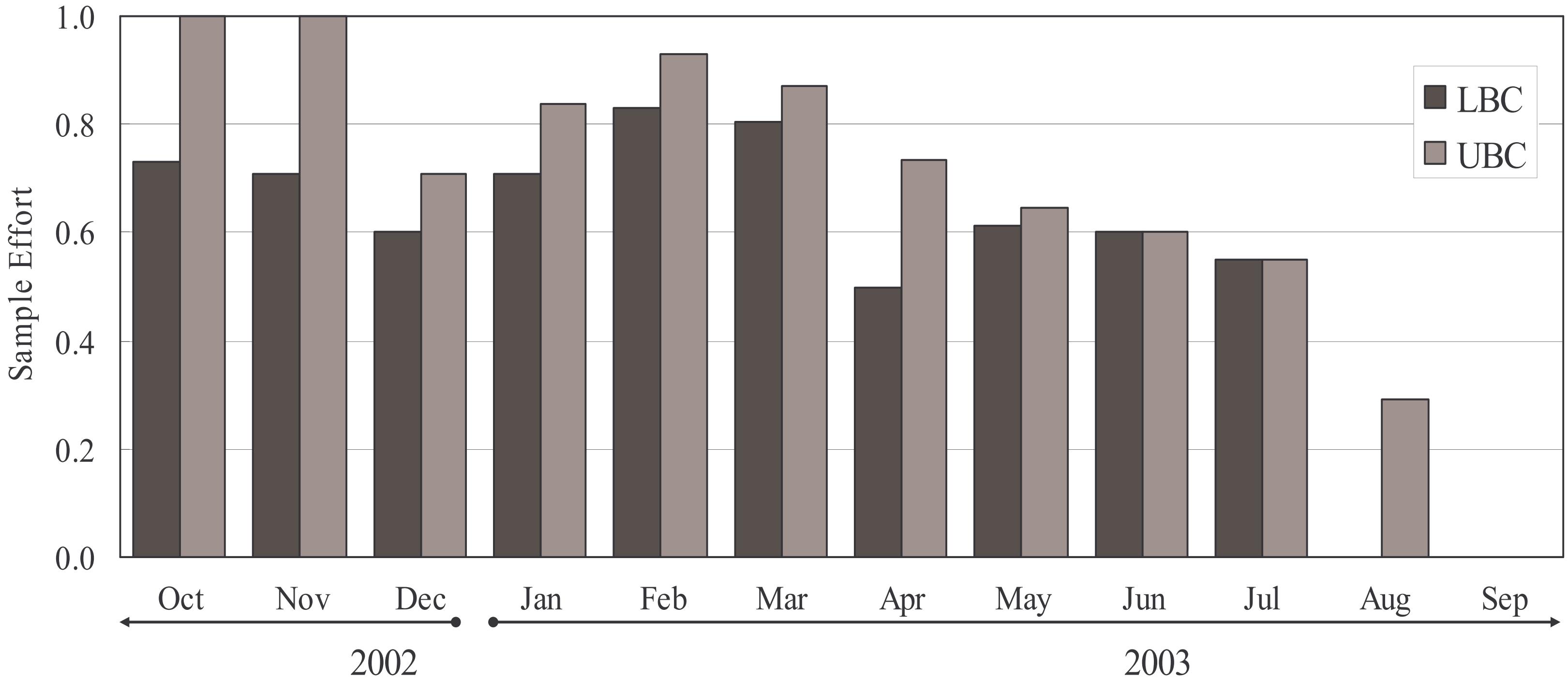

Figure 2. Sampling effort summarized as the proportion (range: 0 to 1) of days fished each month at the Lower and Upper Battle Creek rotary screw traps from October 1, 2002 to September 30, 2003. Neither trap was operated during all or most of August and September 2003.

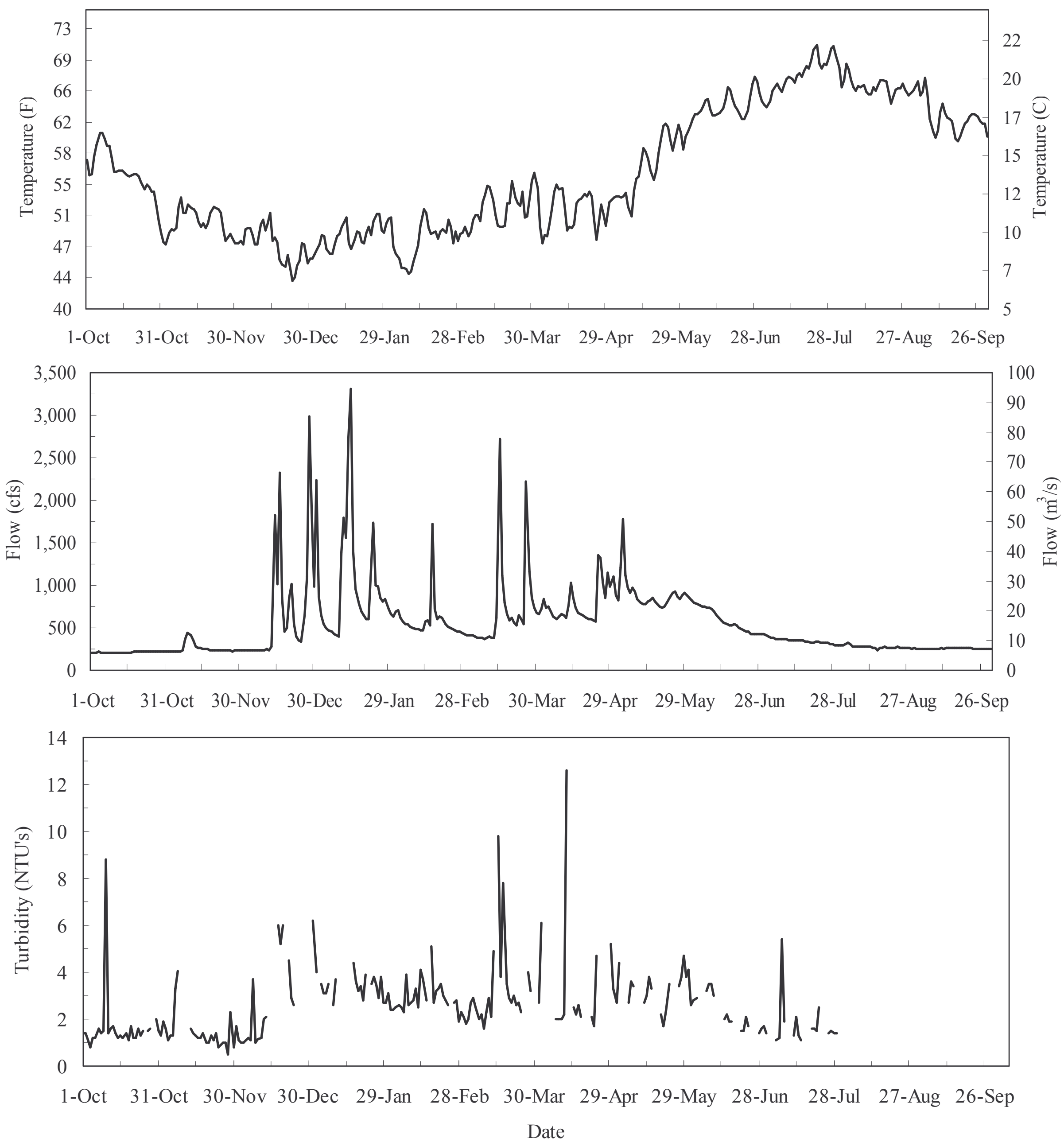

Figure 3. Mean daily temperature (ºC and ºF), mean daily flows (m^3/s and cfs), and turbidity (NTU's) at the Lower Battle Creek rotary screw trap from October 1, 2002 through September 30, 2003.

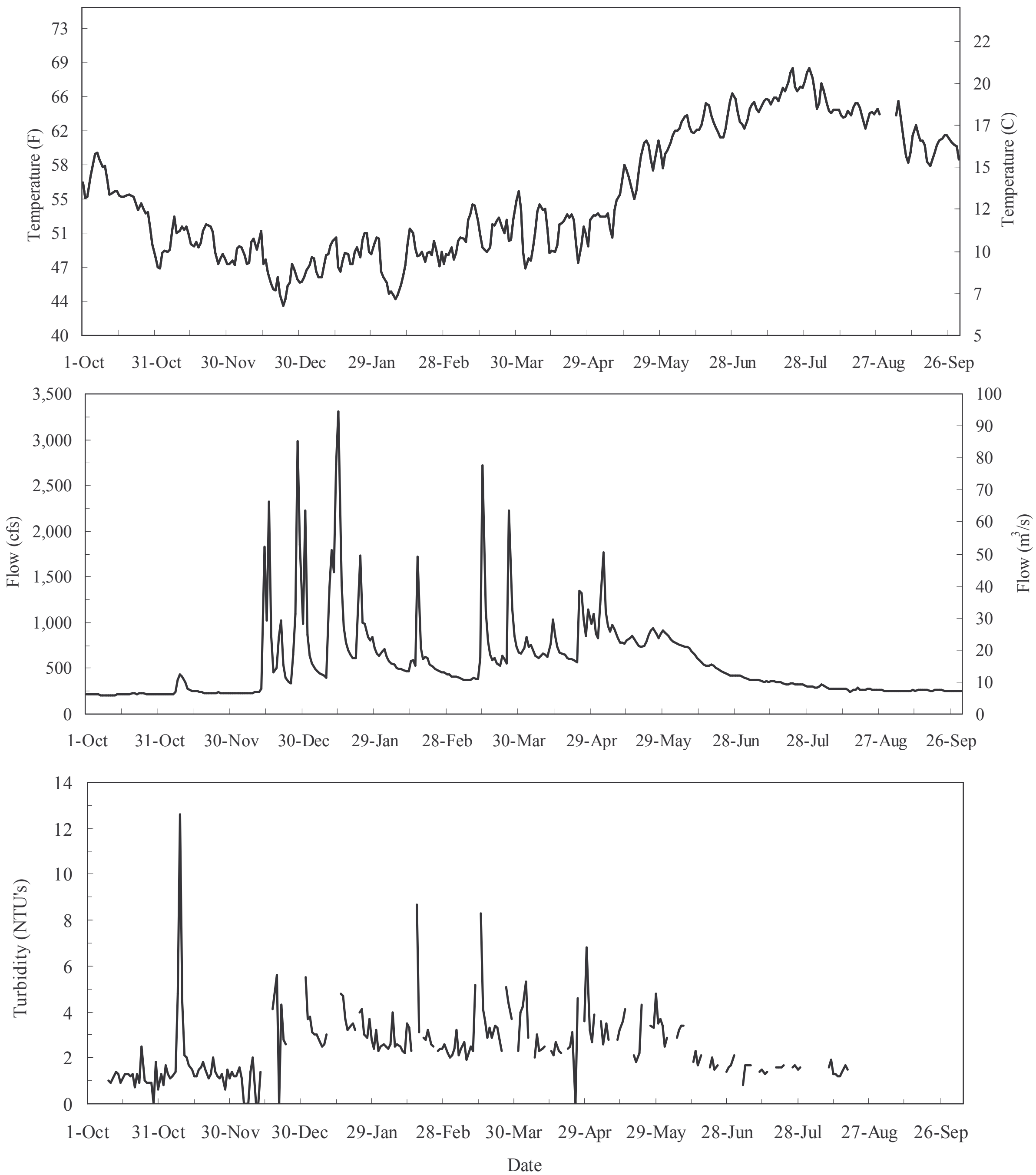

Figure 4. Mean daily temperature (ºC and ºF), turbidity (NTU's), and mean daily flows (m^3/s and cfs), at the Upper Battle Creek rotary screw trap from October 1, 2002 through September 30, 2003.

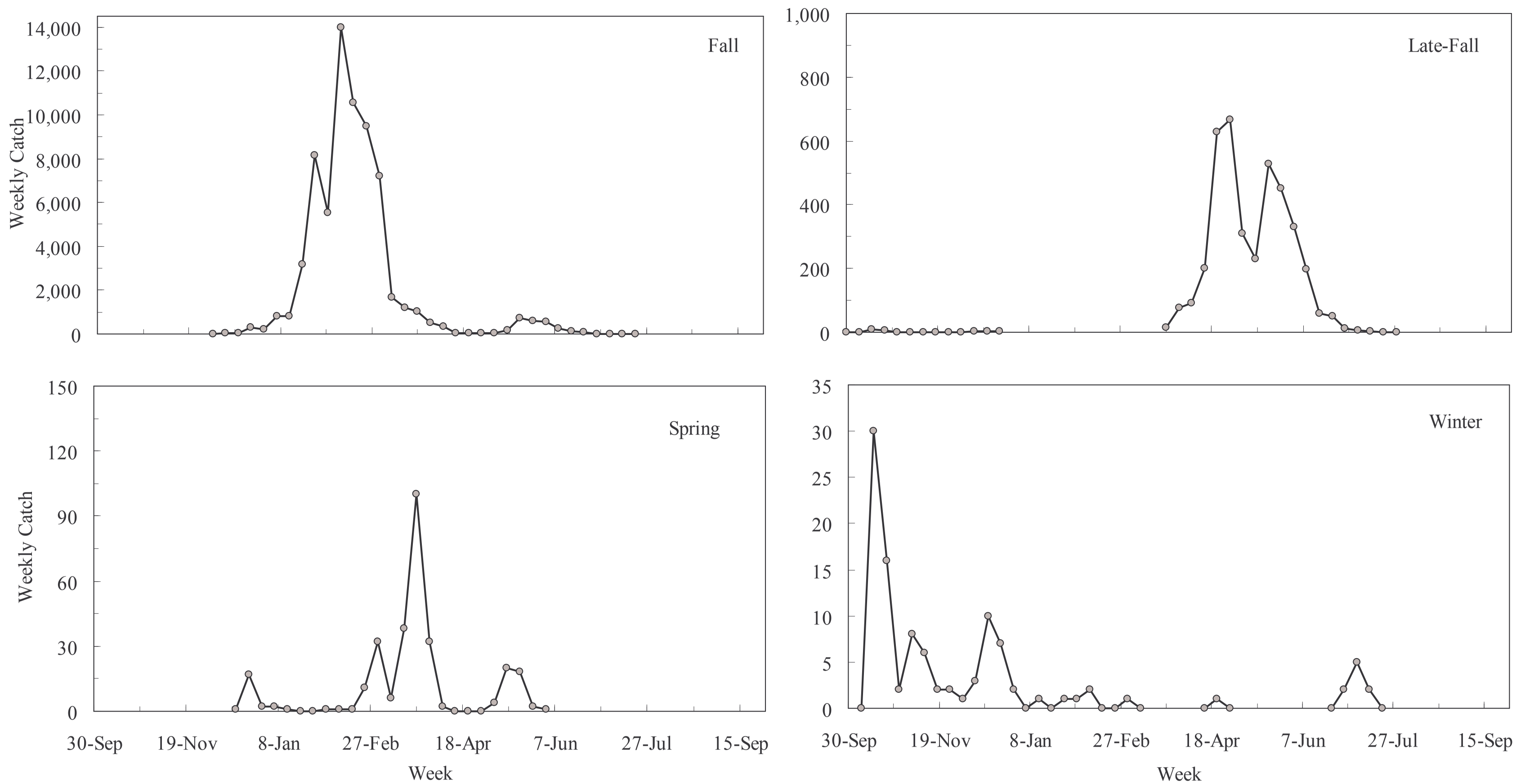

Figure 5. Weekly catch of fall, late-fall, spring, and winter Chinook salmon captured at the Lower Battle Creek rotary screw trap from October 1, 2002 to September 30, 2003. Run designation was assigned using the length-at-date criteria developed for the Sacramento River (Greene1992).

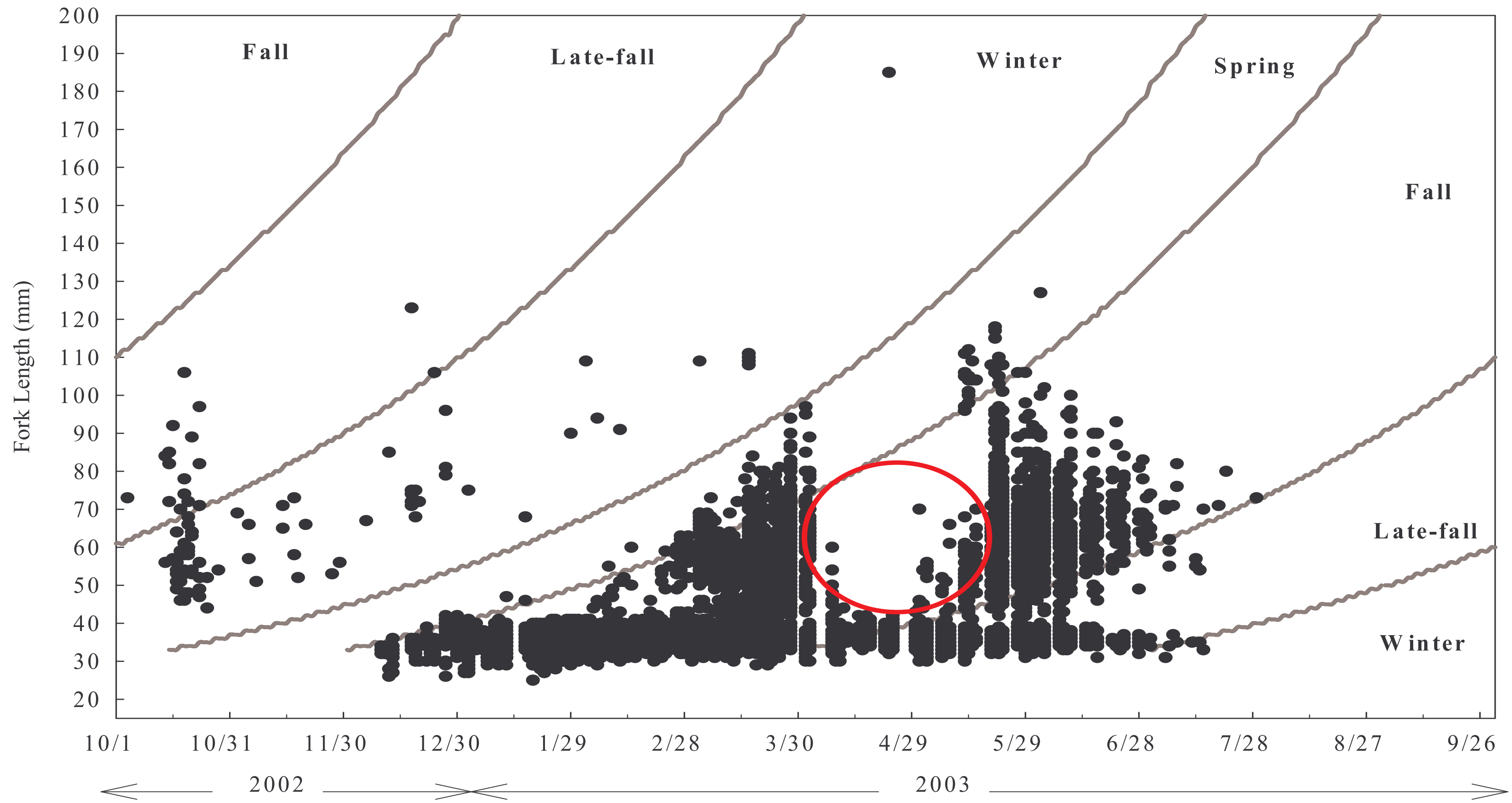

Figure 6. Fork length (mm) distribution by date and run for Chinook salmon captured at the Lower Battle Creek rotary screw trap from October 1, 2002 to September 30, 2003. Spline curves represent the maximum fork lengths expected for each run by date, based upon criteria developed by the California Department of Water Resources (Greene 1992). The circle indicates the period when unmarked hatchery fall Chinook salmon were released. Most Chinook ≥ 45 mm were not includes as they were likely hatchery fish.

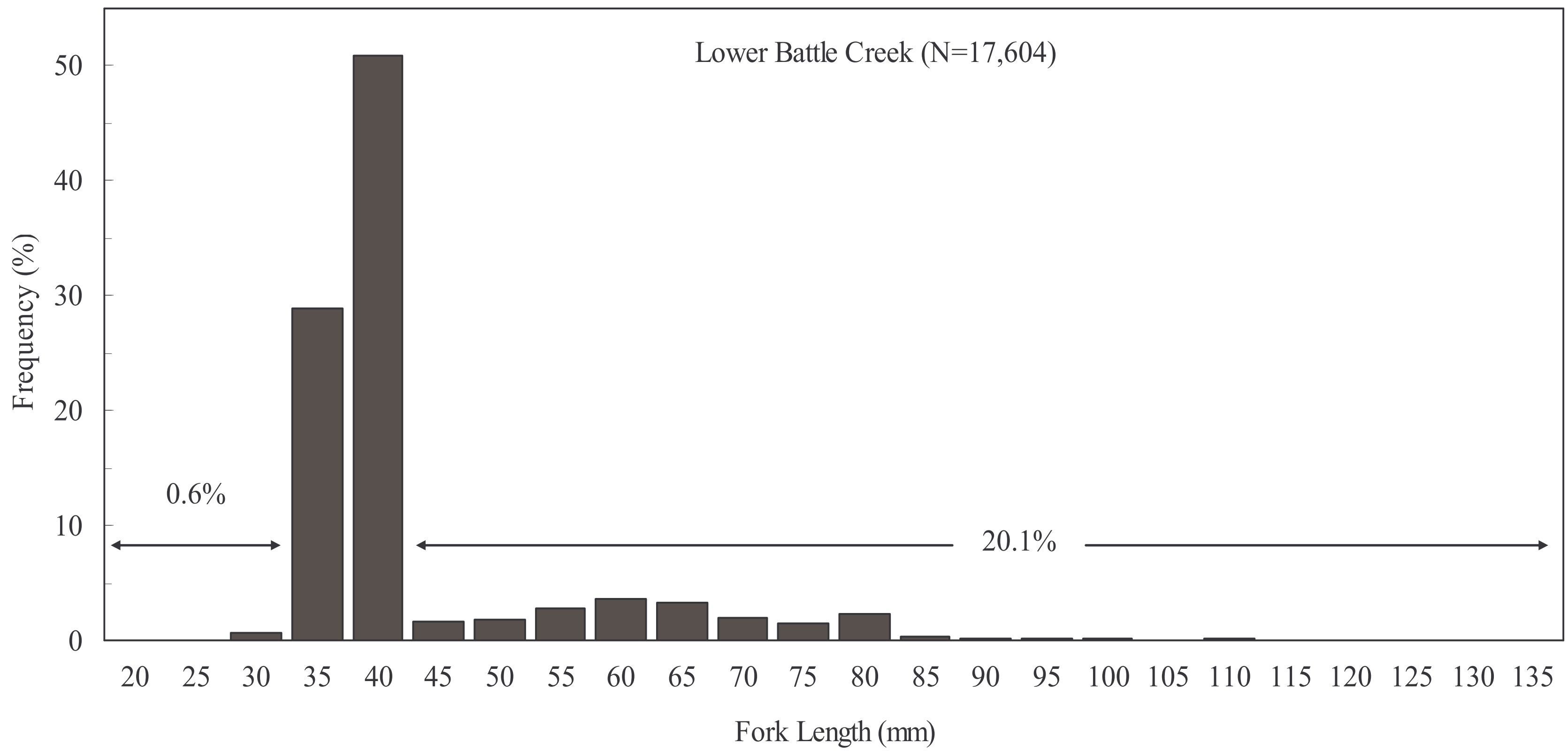

Figure 7. Length frequency (%) for all runs of Chinook salmon measured at the Lower Battle Creek rotary screw trap (LBC) during October 1, 2002 through September 30, 2003. Fork length axis labels indicate the upper limit of a 5-mm length range.

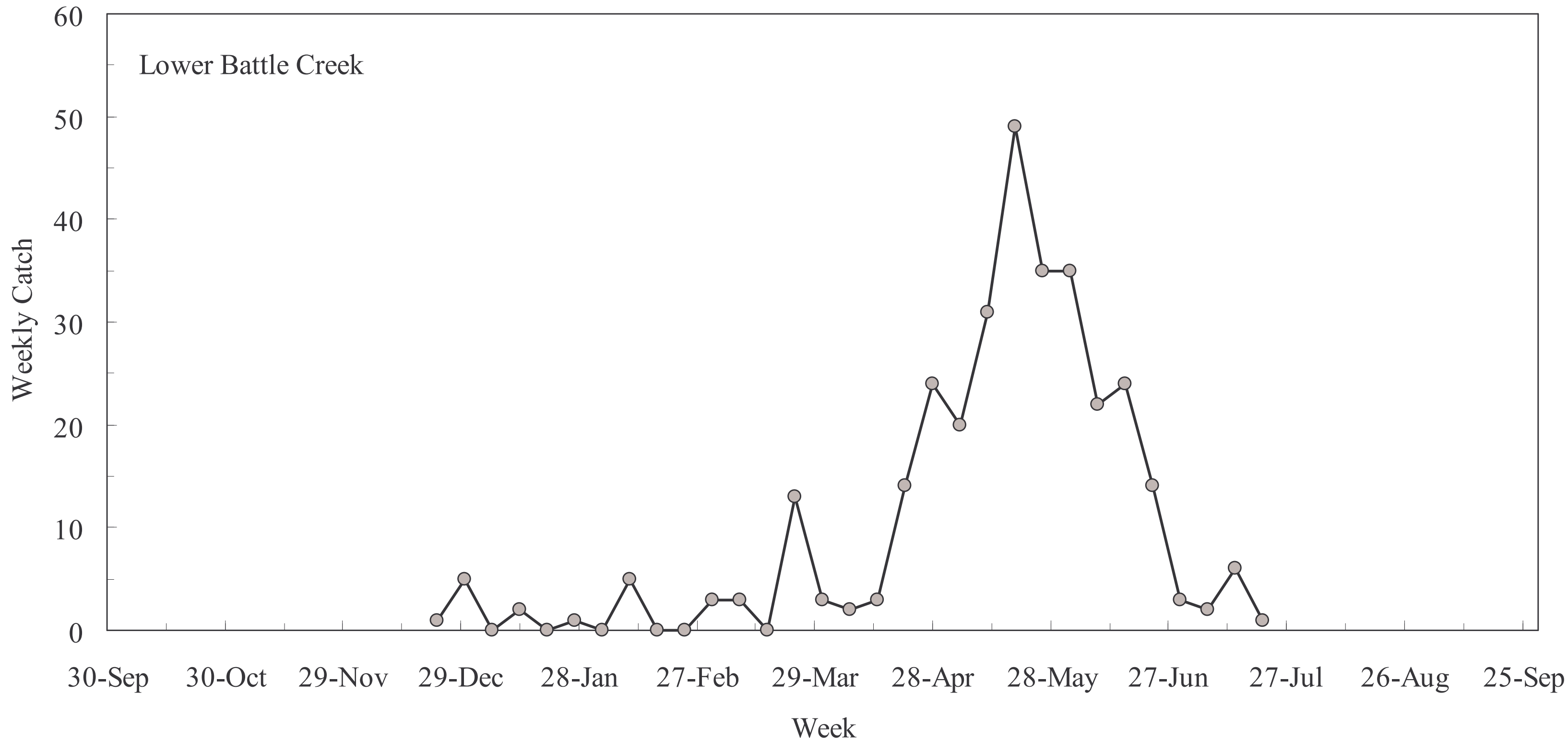

Figure 8. Weekly catch of rainbow trout/steelhead at the Lower Battle Creek rotary screw trap from October 1, 2002 to September 30, 2003.

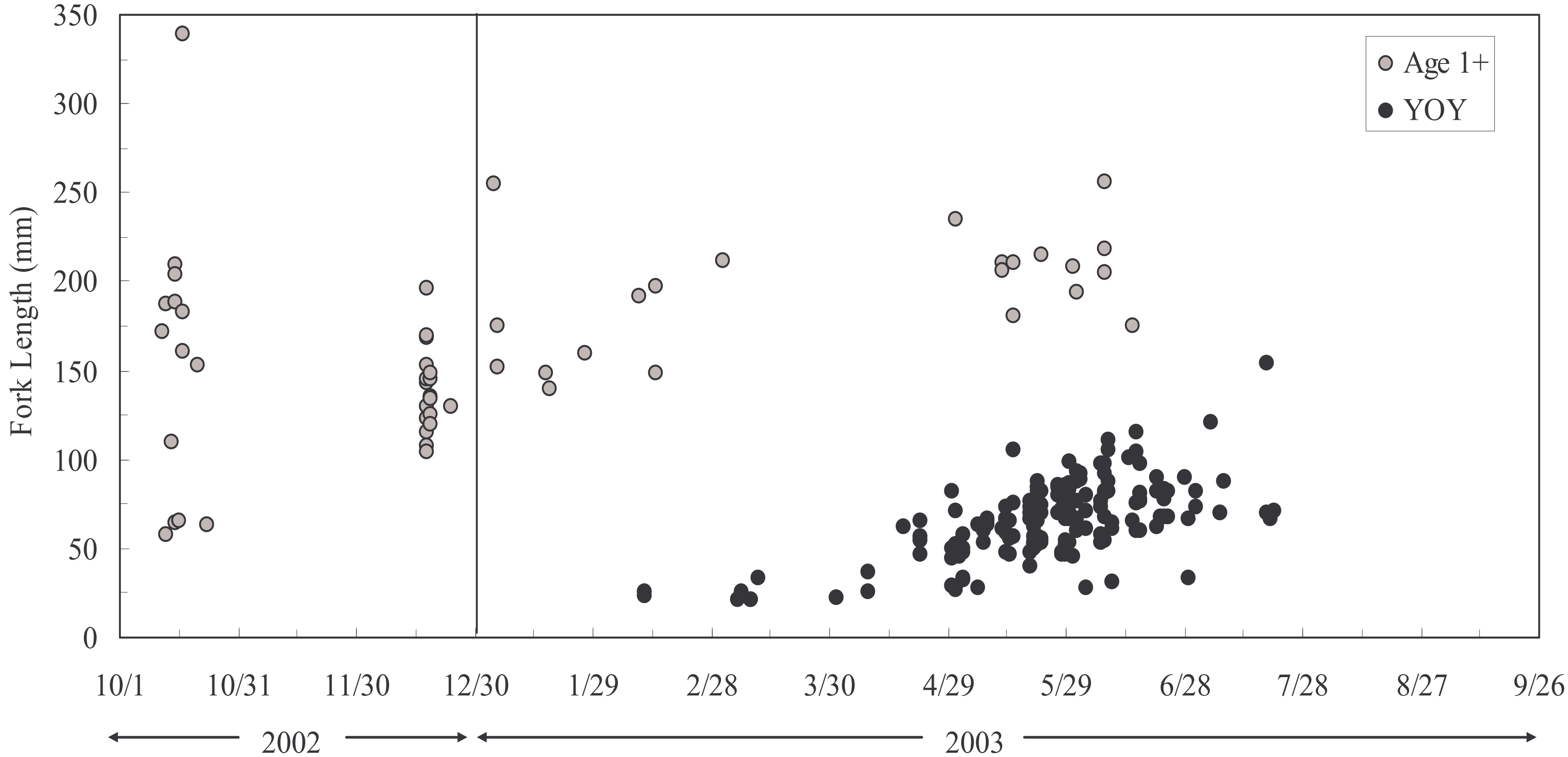

Figure 9. Fork length (mm) distribution for age 1+ and young-of-the-year (YOY) rainbow trout/steelhead sampled at the Lower Battle Creek rotary screw trap during October 1, 2002 through September 30, 2003. Age 1+ fish may include individuals from more than one year class.

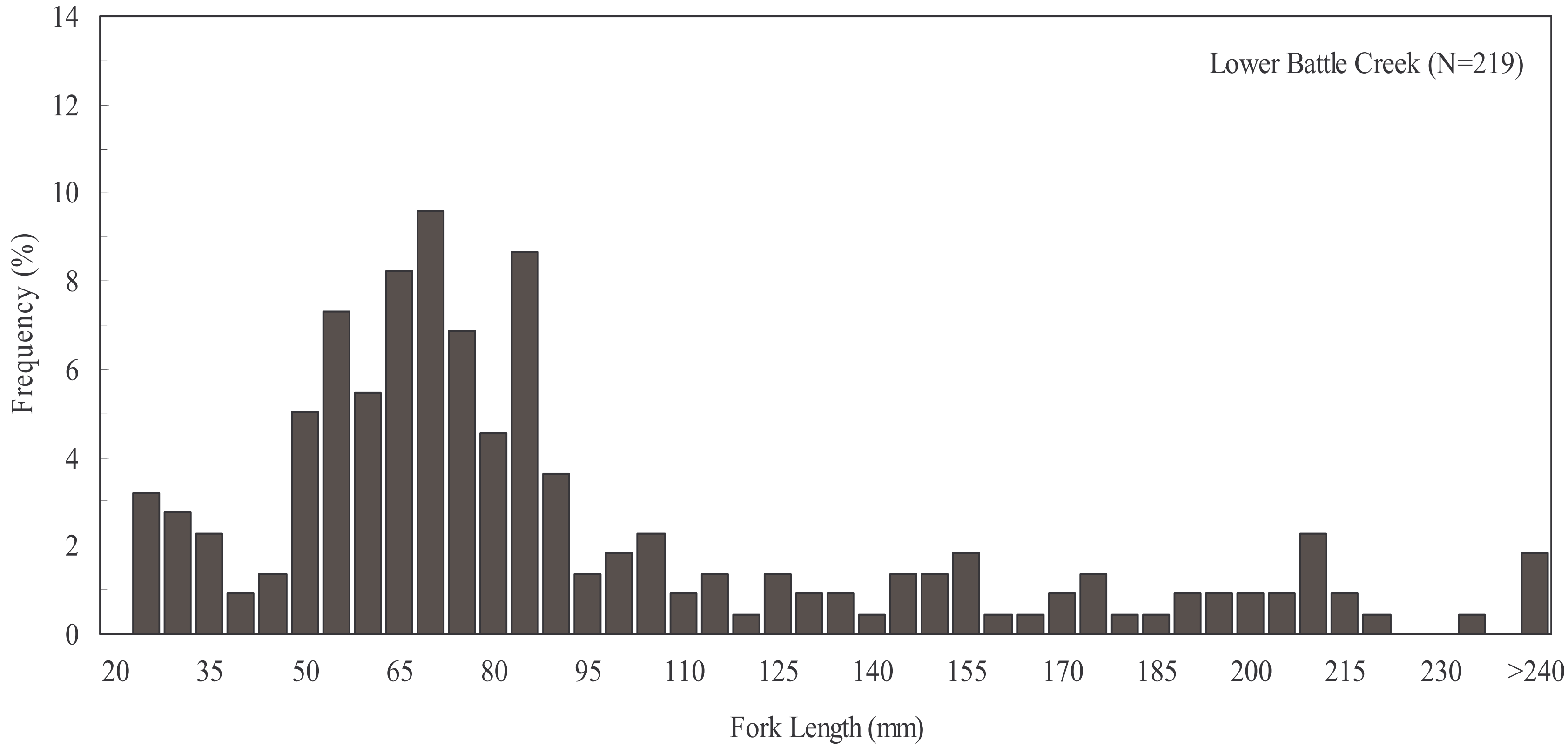

Figure 10. Fork length frequency (%) for rainbow trout/steelhead sampled at the Lower Battle Creek rotary screw trap during October 1, 2002 through September 30, 2003. Fork axis labels indicate the upper limit of a 5-mm length range.

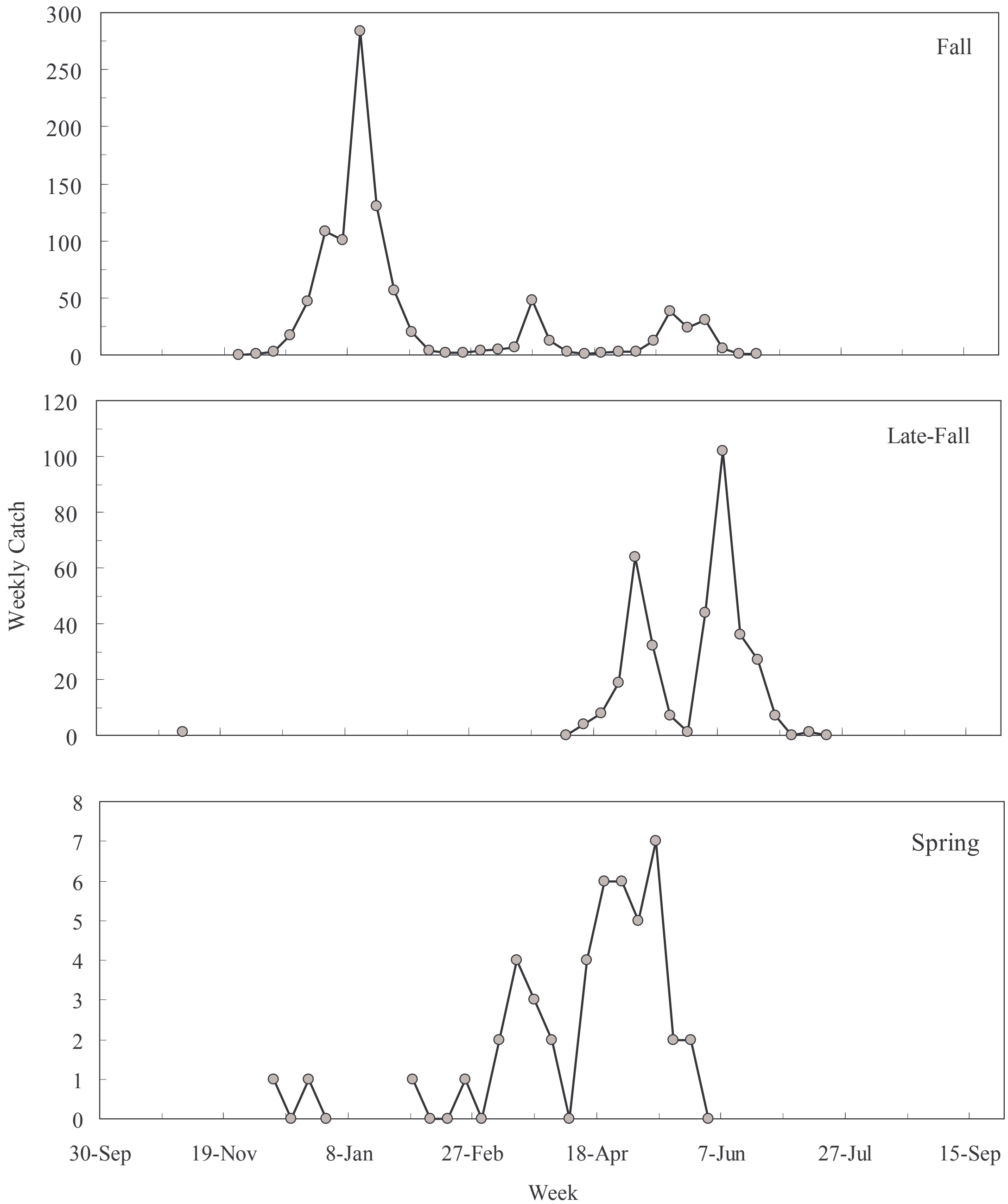

Figure 11. Weekly catch of fall, late-fall, and spring Chinook salmon captured at the Upper Battle Creek rotary screw trap from October 1, 2002 to September 30, 2003. Only one winter Chinook salmon was captured; therefore it was not displayed graphically. Run designation was assigned using the length-at-date criteria developed for the Sacramento River (Greene 1992).

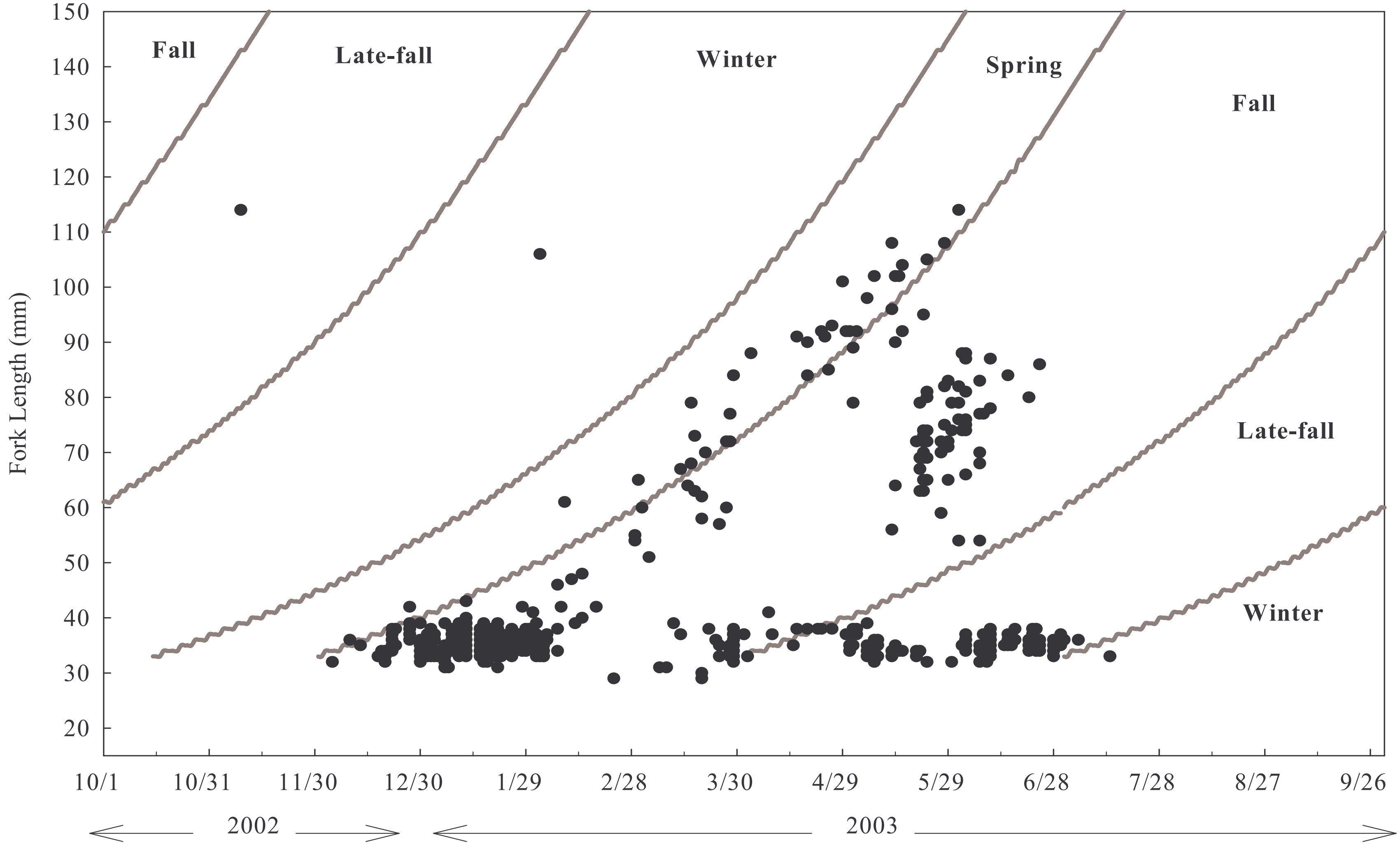

Figure 12. Fork length (mm) distribution by date and run for Chinook salmon captured at the Upper Battle Creek rotary screw trap from October 1, 2002 to September 30, 2003. Spline curves represent the maximum fork lengths expected for each run by date, based on criteria developed by the California Department of Water Resources (Greene 1992).

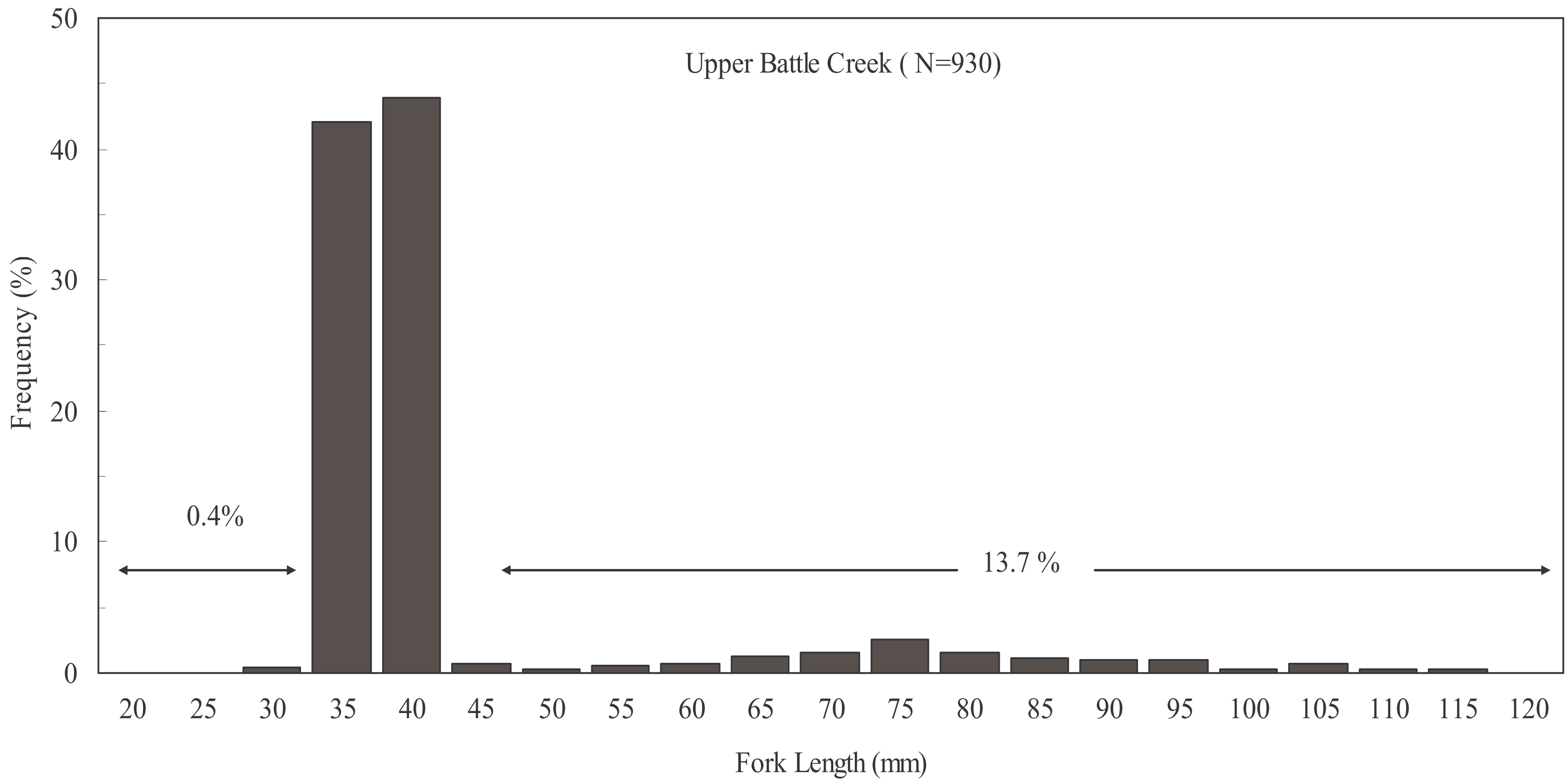

Figure 13. Length frequency (%) for all runs of Chinook salmon measured at the Upper Battle Creek rotary screw trap (UBC) during October 1, 2002 through September 30, 2003. Fork length axis labels indicate the upper limit of a 5-mm length range.

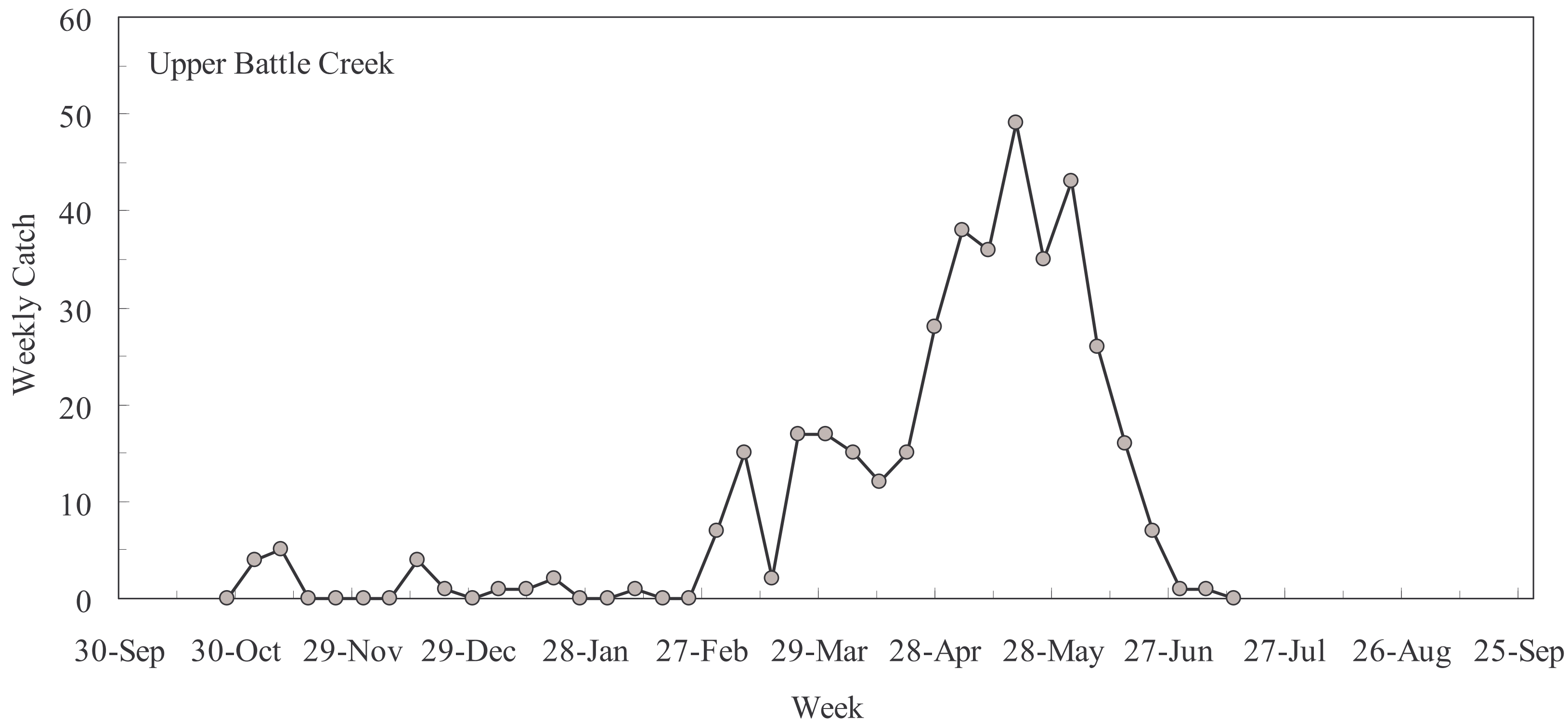

Figure 14. Weekly catch of rainbow trout/steelhead weekly catch at the Upper Battle Creek rotary screw trap from October 1, 2002 to September 30, 2003.

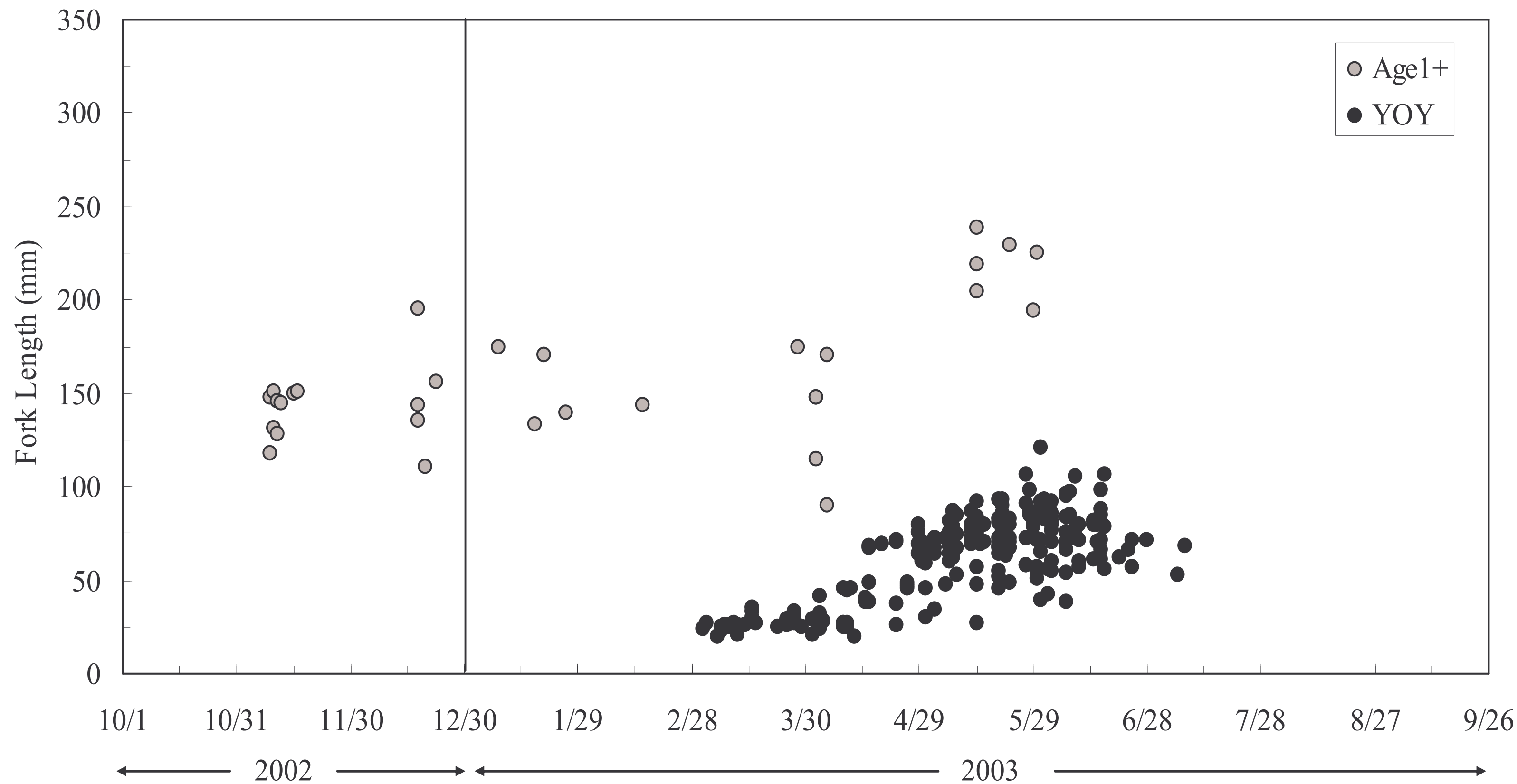

Figure 15. Fork length (mm) distribution by date for age 1+ and young-of-the-year rainbow trout/steelhead measured at the Upper Battle Creek rotary screw trap during October 1, 2002 through September 30, 2003. Age 1+ fish may include individuals from more than one year class.

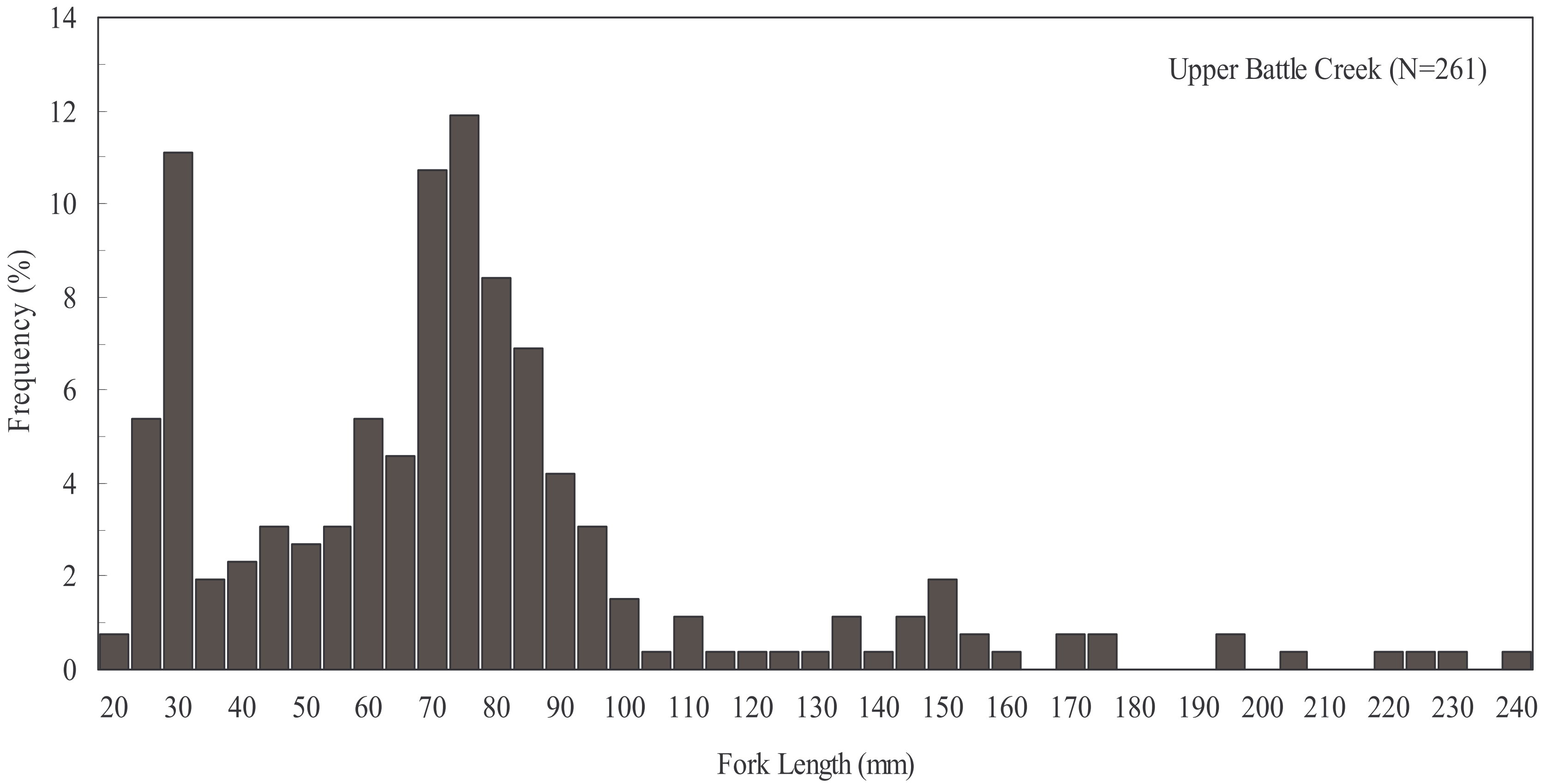

Figure 16. Fork length frequency (%) for rainbow trout/steelhead sampled at the Upper Battle Creek rotary screw trap during October1, 2002 through September 30, 2003. Fork axis labels indicate the upper limit of a 5-mm length range.

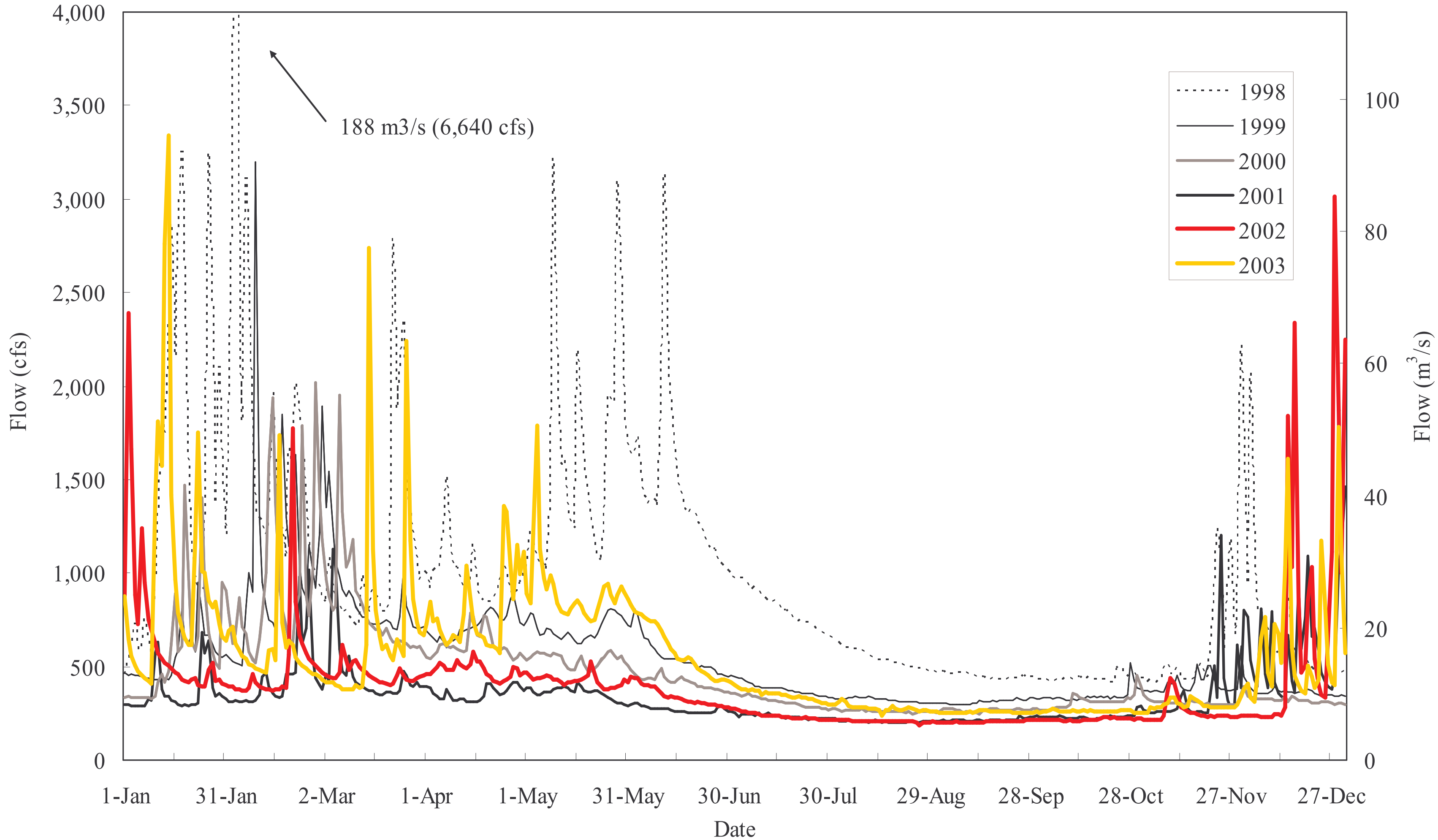

Figure 17. Mean daily flows (m^3/s) recorded at the U. S. Geological Survey gauging station (BAT-#11376550) located below the Coleman National Fish Hatchery barrier weir, 1998-2001.

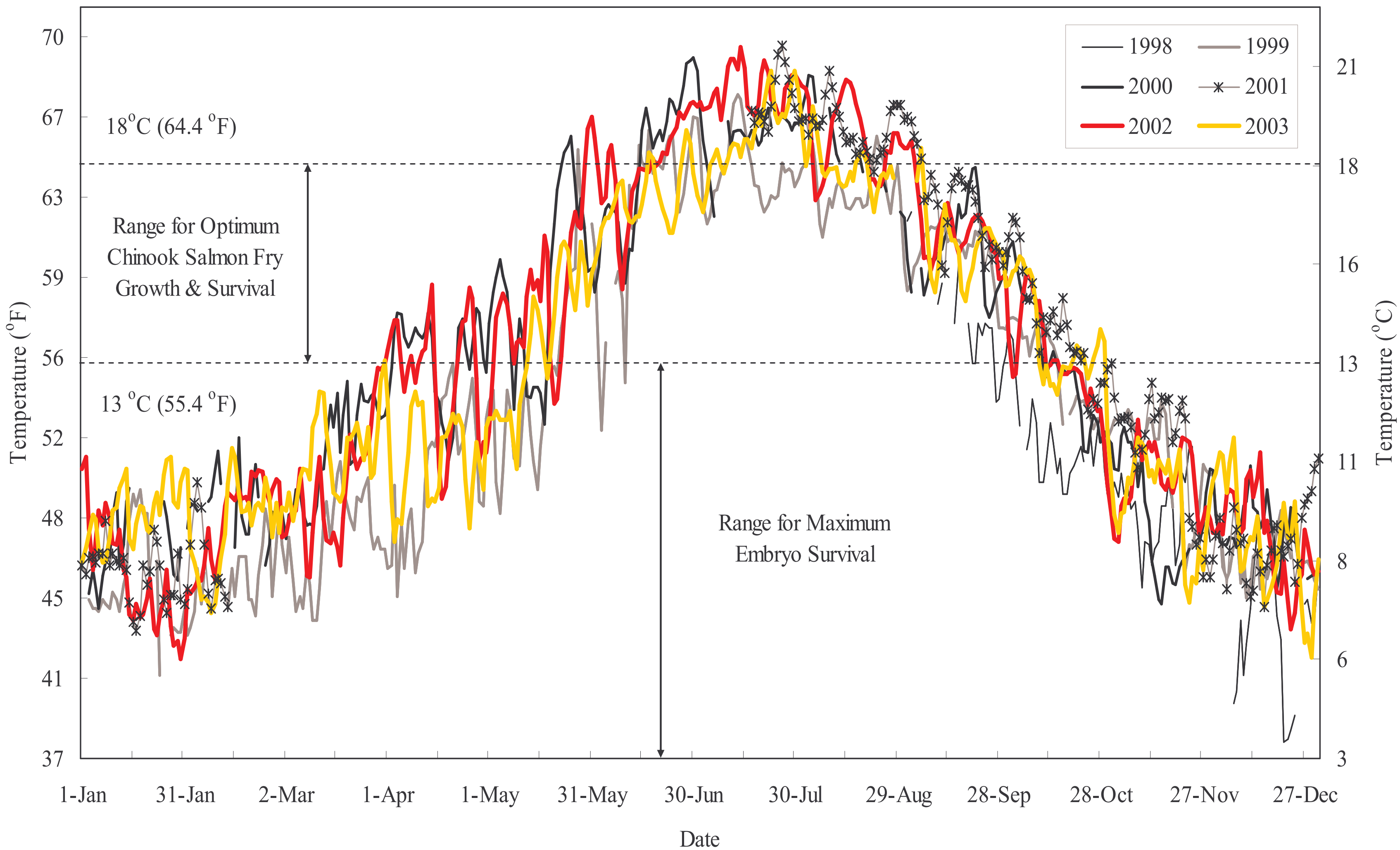

Figure 18. Mean daily water temperatures at the Upper Battle Creek rotary screw trap from 1998 to 2003. Data was not available for periods the traps were not operated in1998 and 2001 when the trap was not operated.

Appendix

Appendix 1. Summary of days the Lower Battle Creek rotary screw trap did not fish during the report period (October 1, 2002 to September 30, 2003), including sample dates, hours fished, and reason for not fishing.

Sample Dates	Hours Fished (approx)	Reason
	2002	
October 22, 2002	24	Bottom screen broken
November 6 and 8, 2002	16 & 6	Trap not Rotating
November 9-11, 2002	0	Late-fall Chinook Hatchery Release
December 14-17, 2002	0	High Flows
December 21, 2002	0	Debris blocking tail screen
December 23, 2002	1.7	Trap not Rotating
December 25-26, 2002	0	Christmas Holidays
December 28-29 and 31, 2002	0	High Flows
	2003	
January 3, 2003	0	Late-fall Chinook Hatchery Release
January 8, 2003	0	Unknown
January 11 and 13-15, 2003	0	High Flows
January 16, 2003	0	Late-fall Chinook Hatchery Release
January 23, 2003	0	High Flows
February 10, 2003	24	Sample Compromised
February 16, 2003	0	High Flows
February 25, 2003	0	Meeting
March 15 and 26-27, 2003	0	High Flows
March 29-31, 2003	0	Trap Repair
April 3-4, 2003	0	Tree Removal
April 5-7, 2003	0	Fall Chinook Hatchery Release
April 13-14, 2003	0	High Flows
April 19-21, 2003	0	Fall Chinook Hatchery Release
April 25-29, 2003	0	Fall Chinook Hatchery Release
May 4-5, 2003	0	Reduced Schedule/Limited Staff
May 6, 2003	0	Sample Compromised
May 10-12, 17-19, 24-26, 2002	0	Reduced Schedule/Limited Staff
June 4-6, 11-13, 18-20, 25-27, 2003	0	Reduced Schedule/Limited Staff
July 2-4, 9-11, 16-18, 23-25, 2003	0	Reduced Schedule – Few Salmonids
July 30 to September 30, 2003	0	Trap Out/Little or No Outmigration

Appendix 2. Summary of days the Upper Battle Creek rotary screw trap did not fish during the report period (October 1, 2002 to September 30, 2003), including sample dates, hours fished, and reason for not fishing.

Sample Dates	Hours Fished	Reason
	2002	
December 14-17, 2002	0	High Flows
December 25-26, 2002	0	Christmas Holidays
December 28-29 and 31, 2002	0	High Flows
	2003	
January 11 and 13-15, 2003	0	High Flows
January 23, 2003	0	High Flows
February 16, 2003	0	High Flows
February 25, 2003	0	Meeting
March 15 and 26, 2003	0	High Flows
March 30-31, 2003	0	Reduced Schedule/Limited Staff
April 4-7, 13-14, 20-21, 2003	0	Reduced Schedule/Limited Staff
April 25, 2003	0	High Flows
April 27-28, 2003	0	Reduced Schedule/Limited Staff
May 4-5, 10-12, 17-19, 24-26, 2003	0	Reduced Schedule/Limited Staff
June 4-6, 11-13, 18-20, 25-27, 2003	0	Reduced Schedule/Limited Staff
July 2-4, 9-11, 16-18, 2003	0	Reduced Schedule/Limited Staff
July 30 to August 9, 2003	0	Trap Out/ Little or No Outmigration
August 19 to September 30, 2003	0	Trap Out/ Little or No Outmigration